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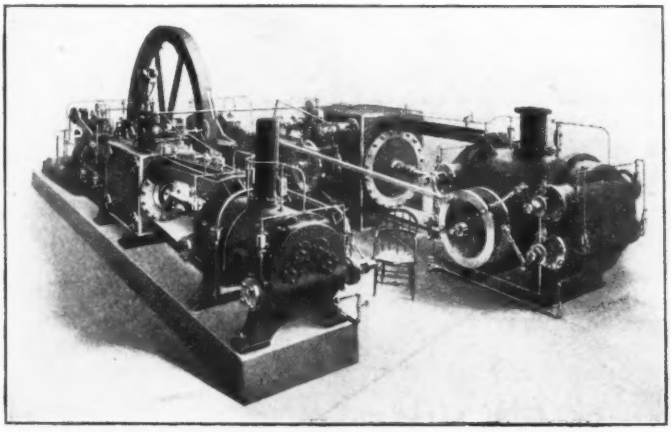

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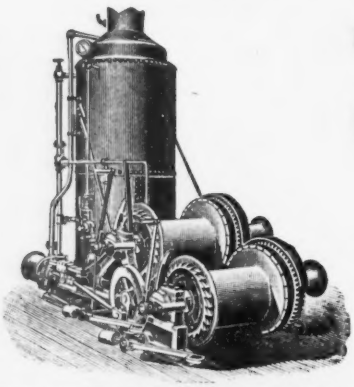

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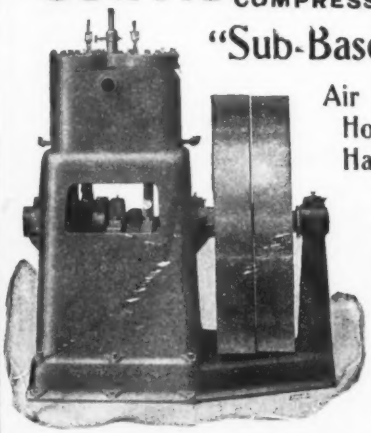

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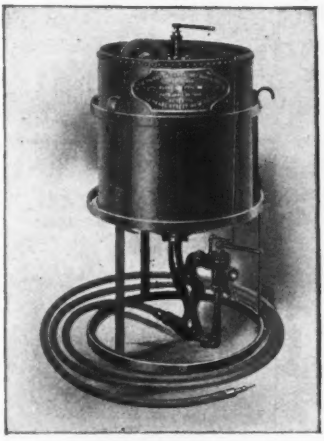

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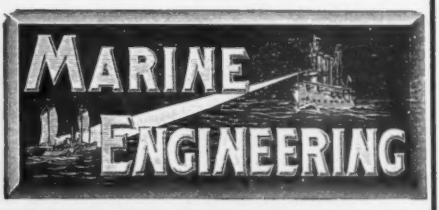

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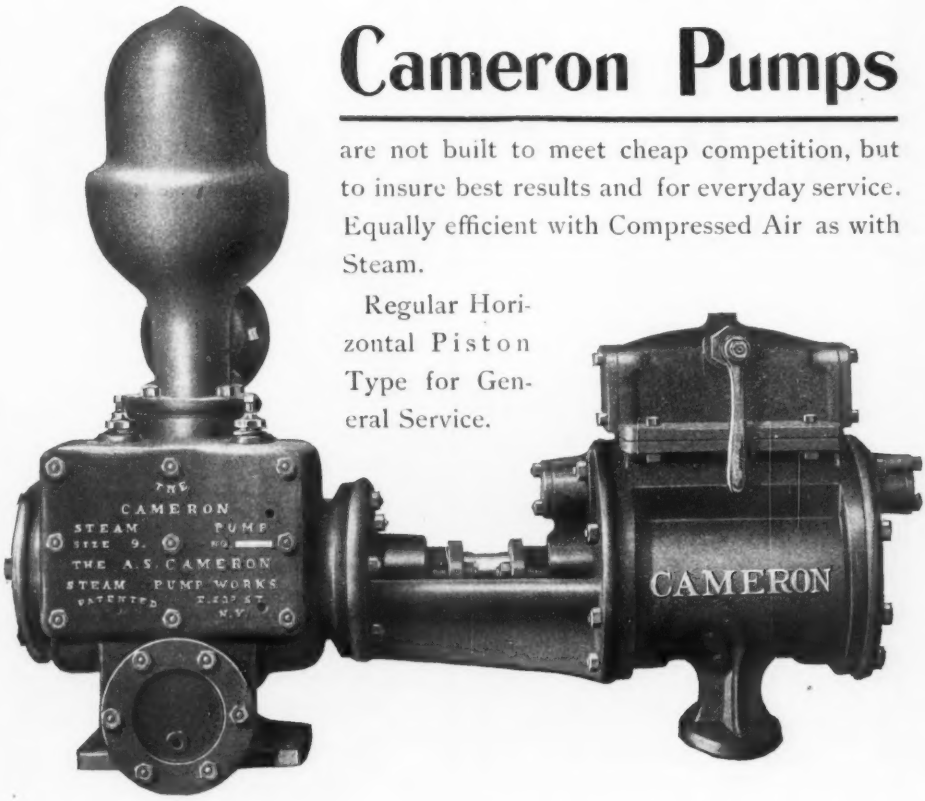

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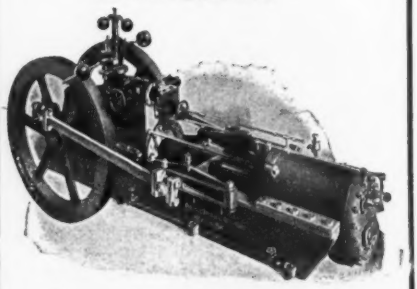

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VOL. X. AUGUST, 1905. NO. 6

Economy Through Reheating.

As a means of power transmission compressed air is beginning to receive the careful study that it deserves. It is an old story how air was expected to accomplish great things and yet received comparatively no attention or care. From this grew the fallacy that there was no economy in the use of compressed air. As soon as the pneumatic engineer became a reality he proved how false that statement was.

One of the first steps in the economical use of air was the adoption of the intercooler. When the advantages of compound compression for higher pressures began to be appreciated the intercooler became a very necessary and important part.

Trouble in the air line and at the drill or motor developed from the moisture in the air. The solution of this problem appeared in the form of an aftercooler. Compressed air plants designed on modern lines include the aftercooler in some form in every instance. Pneumatic engineers fully realize the advantages to be gained from aftercooling, even if a certain amount of energy is lost as the heat disappears.

The reverse of this proposition, the restoration of this heat just previous to the expansion of the air, is an economy which, while admitted in theory, is rarely put into actual operation. As air is heated it expands. Therefore the air under pressure, if heated, will have a greater expansive force or pressure. In expanding the temperature of air is lowered. For this reason reheating often serves as a remedy for freezing at the exhaust of the machine. It has been proven, however, that with proper attention to the removal of moisture from the air there will be no freezing, even if the air enters the motor at a comparatively low temperature. The great advantage which reheating offers is an increased efficiency for the air under pressure.

The leading article in this issue is a treatise on the subject of reheating, which will be read with interest by those who are interested in the economical use of compressed air. The paper is too long to publish in one issue, and it will be concluded in the September number. COMPRESSED AIR will be glad to publish any comments which its readers may care to make on the statements made therein.

Destruction of Henderson's Point.

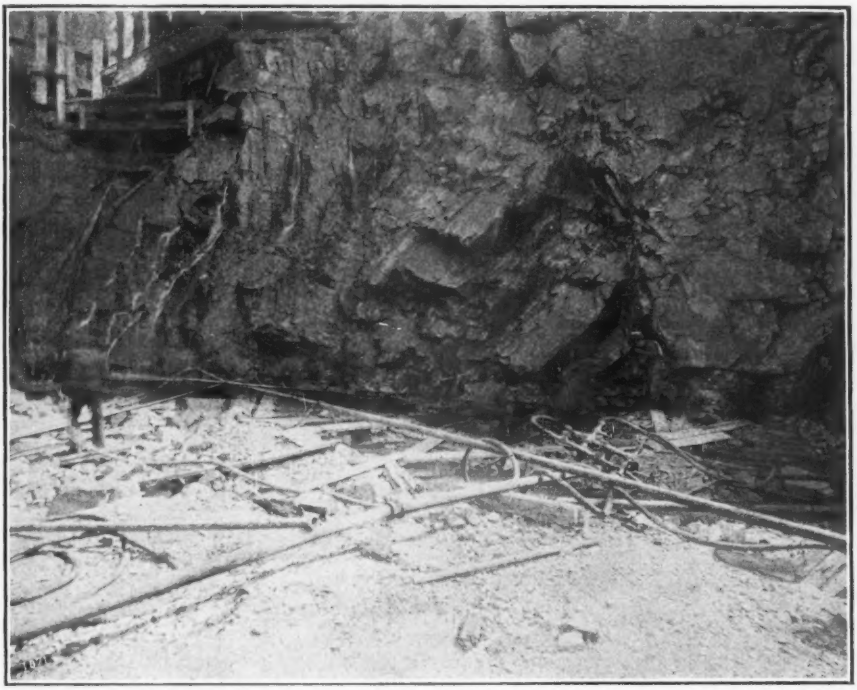
Certain new and distinguishing features in the field of rock excavation have gained special prominence for the destruction of Henderson's Point at the Portsmouth Navy Yard, Kittery, Maine. The removal of this rocky point was made necessary in the widening and straightening of the channel of the Piscataqua River, so that the large war ships might reach the new dry-dock recently completed at Kittery. Henderson's Point projected out into the river, making a sharp turn in the swift current around which the larger ships

SEVEN INGERSOLL-SERGEANT "H-9" DRILLS AT WORK AT HENDERSON'S POINT. THIS ILLUSTRATES THE METHOD OF MOUNTING, THE DRILLS BEING BOLTED FAST TO A TIMBER FRAMEWORK, WHICH IS LOADED WITH STONE.

could not pass. For the purpose of its removal, $750,000 was appropriated by the Government and the contract for the work awarded to the Massachusetts Construction Company. The inner part, or core of the point was first removed by open-cut work, then, on Saturday, July 22d, the remaining "rim" was destroyed in one blast.

Much has been said about this explosion which has been called by some the largest blast ever fired. As a matter of fact, the total amount of explosive used was by no means as large as that fired at Hell Gate in 1885. The Hell Gate blast extended over an area of 9 acres; 270,000 cubic yards of rock were broken up, and 120 tons of "Rend-rock" powder and 20 tons of dynamite were used. In the blast at Henderson's Point, the "rim" included approximately 35,000 cubic yards of rock and 40 tons of 75 per cent. dynamite were used, or a little more than two pounds of dynamite per cubic yard of rock. This was the largest dynamite blast on record.

Had ordinary conditions prevailed the task would have been a comparatively simple one. It was the intention to begin work in the channel where the slope toward the shore began and, with the aid of a submarine drilling scow, to gradually break off the rock to the required depth, until the shore line was reached. In the meantime, the centre of the Point was to be removed as in ordinary open-cut work. A coffer-dam was to be built outside of the Point, the water pumped out and the "rim" removed in the open. The hitch came in getting a coffer-dam that would stay. A strong one was built, but a few days of the rushing current demolished it. The contractors then realized that this



SIX INGERSOLL-SERGEANT "H-9" DRILLS IN LINE, DRILLING 60-FOOT HOLES IN THE EDGE OF THE "RIM."

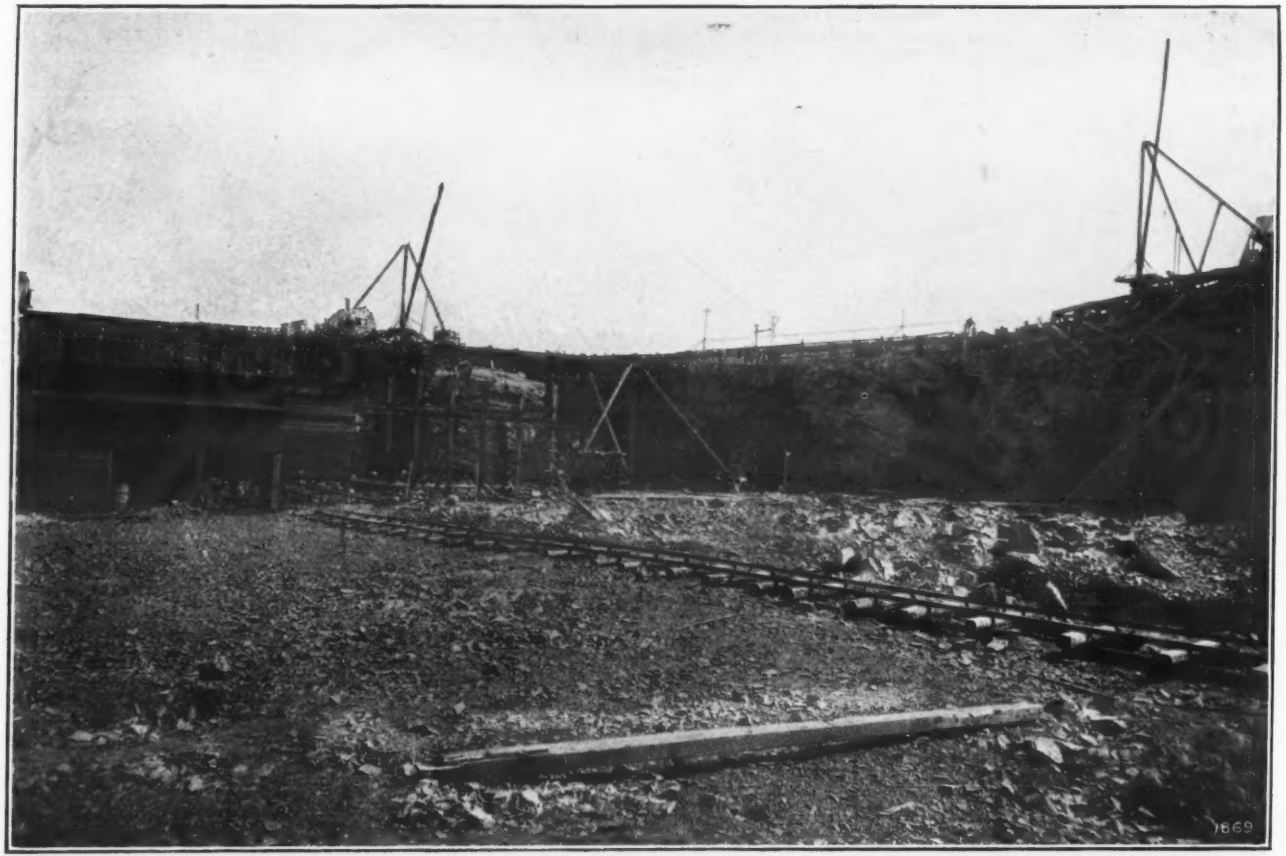
method of excavation could not be followed except at a prohibitive cost.

Bearing in mind the removal of the rock at Hell Gate, consideration was given to a proposition to drive a number of short headings from the inside of the "rim" under the outlying rock, drilling from the headings short holes for the powder. Here another obstacle was discovered in the kind of rock encountered. It was so full of seams and fissures that it was evident there would be great trouble in keeping the water from leaking through into the headings. This difficulty was finally overcome by subsituting long holes from the edge of the "rim" for the headings and short holes. These holes were placed from 6 to 10 feet apart at a dip from the horizontal of 1¼ inches to the foot. In order to reach under all the rock to be removed these holes had to be drilled from 50 to 80 feet deep.

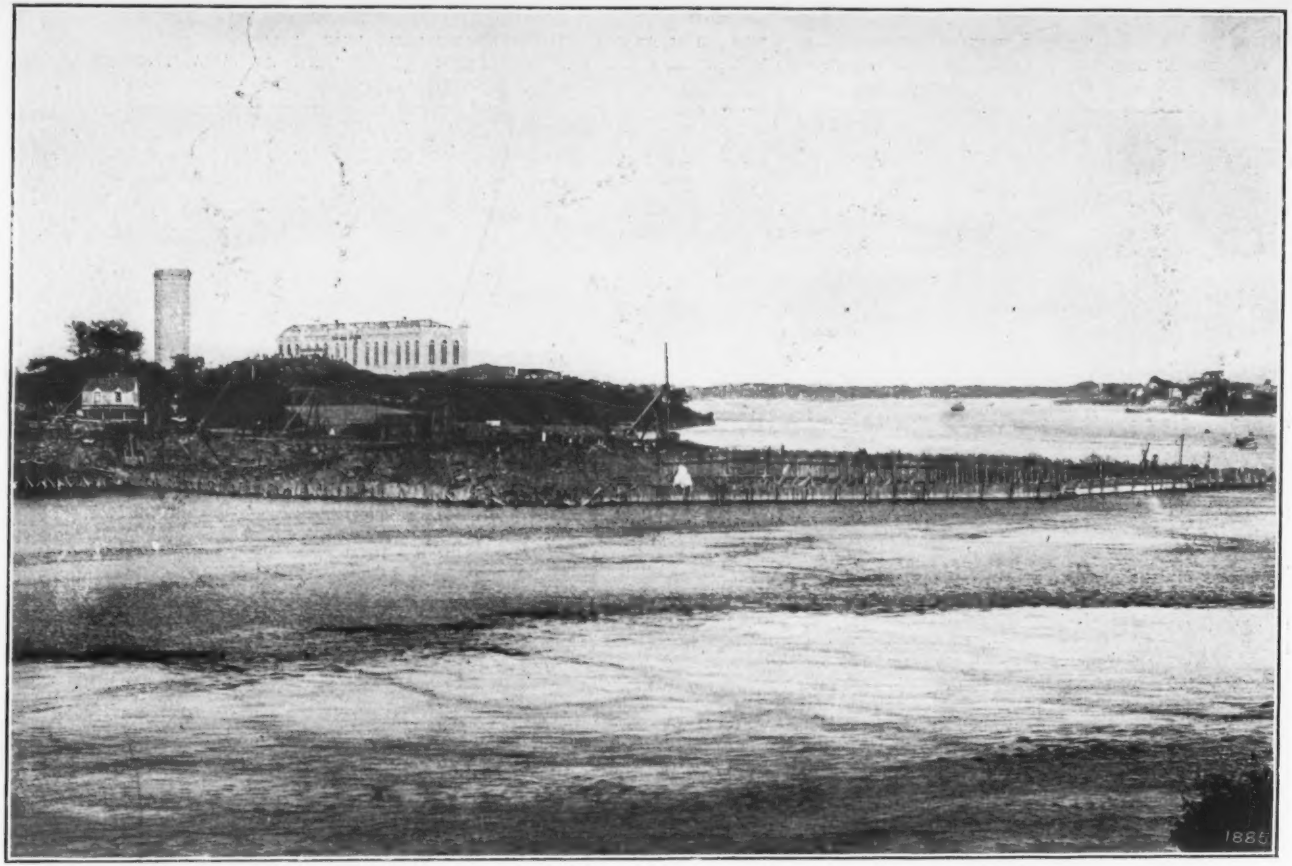
The work of excavation began with the removal of the core. The submarine drilling boat of the Eastern Dredging Company was used just below the Point, drilling holes where the shallow water began. The rock was blasted off into deep water and left there, the intention being to remove it with dredges at the completion of the work. After drilling for three months scows were substituted for the boat and the work continued for a time, about 800 cubic yards of rock being removed in all.

The failure of the coffer-dam made necessary the changes in the plans already mentioned. When the centre of the Point

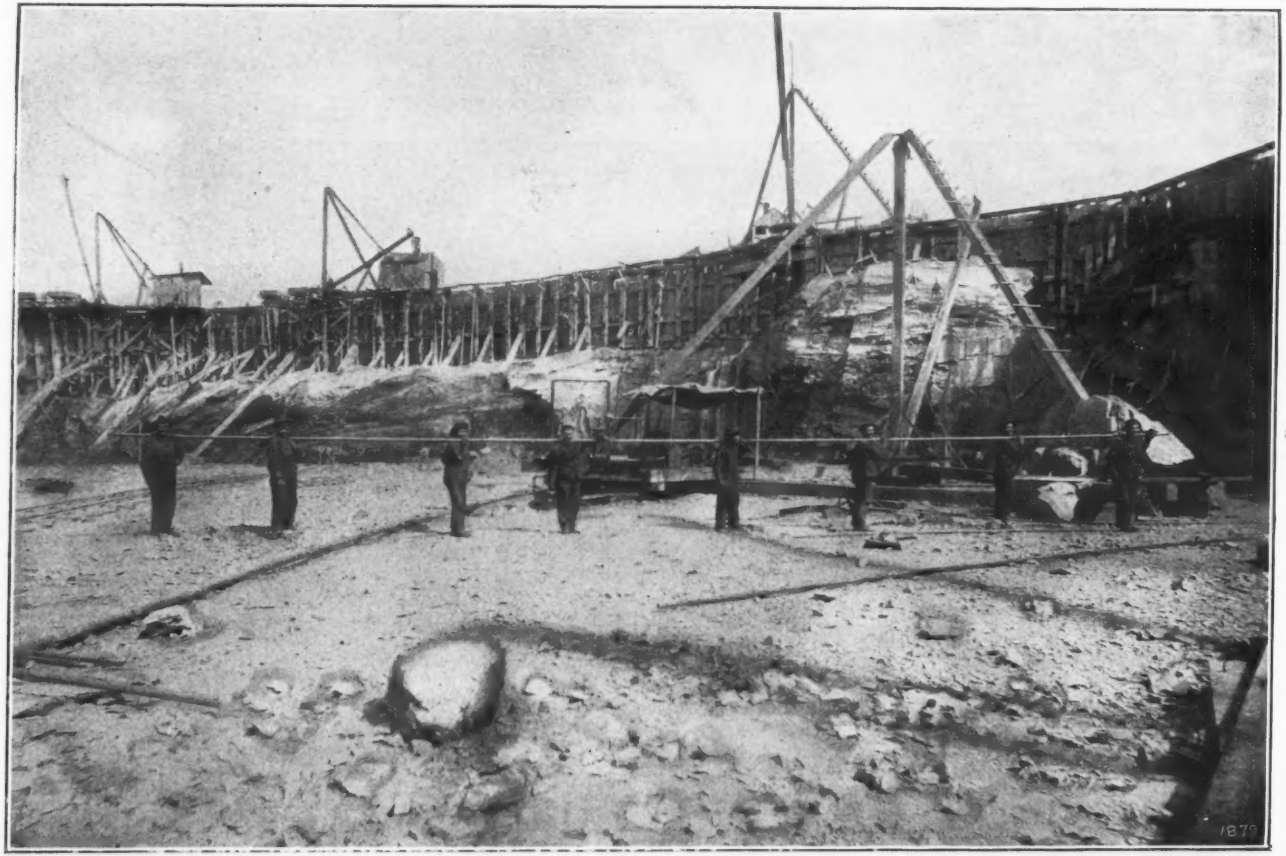
ONE OF THE INGERSOLL-SERGEANT "H-9" DRILLS USED AT HENDERSON'S POINT, ILLUSTRATING THE METHOD OF MOUNTING AND THE USE OF A SHORT EXTENSION PIECE SOMETIMES USED WHEN THE STEELS WERE NOT OF SUFFICIENT LENGTH.



A GENERAL VIEW OF HENDERSON'S POINT, PREVIOUS TO THE BLAST, SHOWING THE EXCAVATION AND THE INSIDE OF THE "RIM." THE COFFER-DAM ON TOP OF THE "RIM" IS VISIBLE IN SEVERAL PLACES.

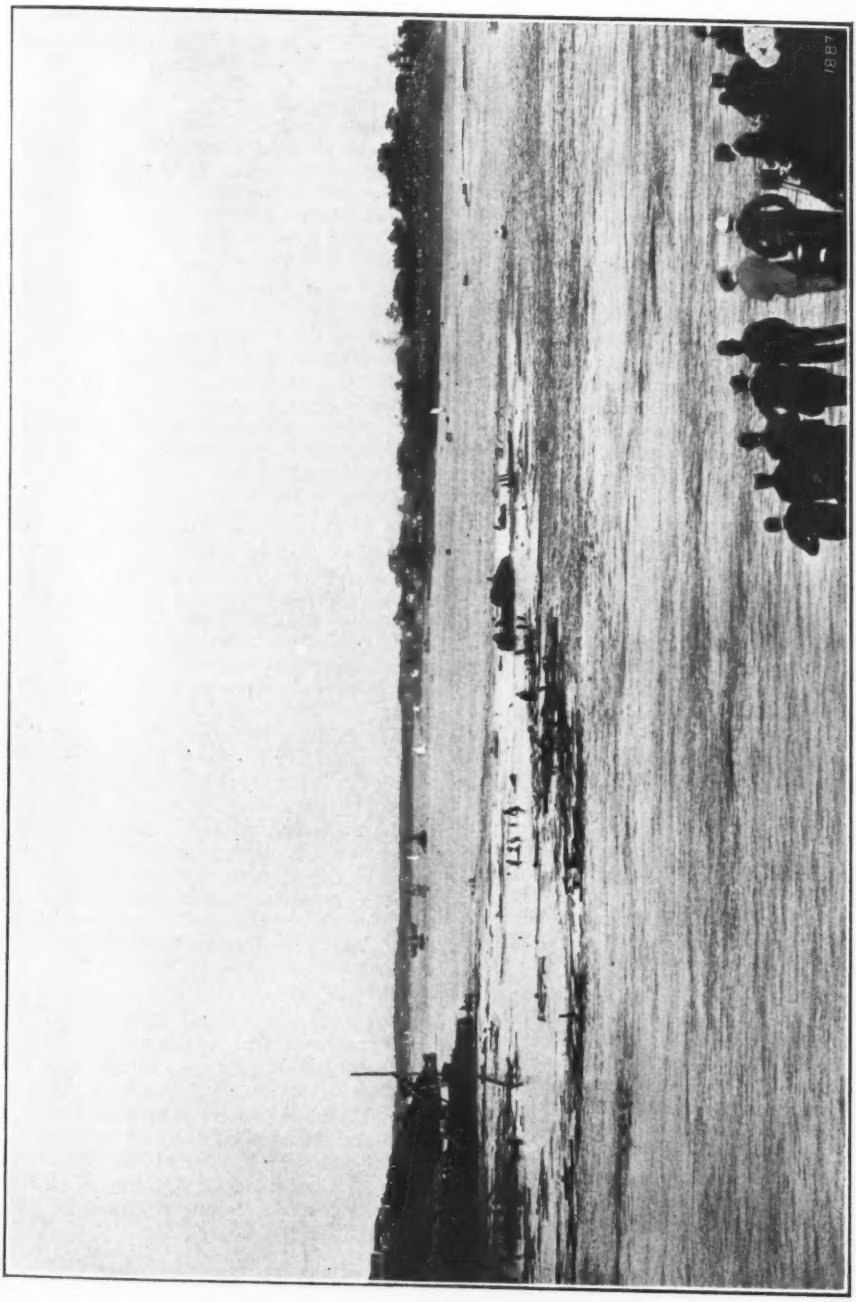


HENDERSON'S POINT, PREVIOUS TO THE BLAST, AS SEEN FROM THE OPPOSITE BANK OF THE PISCATAQUA RIVER. THE LARGE BUILDING IN THE BACKGROUND IS THE NEW NAVAL PRISON. THE SMALL BUILDING AT THE LEFT IS THE OFFICE OF SUPERINTENDENT O. A. FOSTER.



EIGHT MEN CARRYING A 68-FOOT DRILL STEEL FROM THE BLACKSMITH SHOP TO THE SIDE OF THE "RIM" WHERE THE DRILLS WERE IN OPERATION.

AN INSTANTANEOUS PHOTOGRAPH OF THE BLAST AT HENDERSON'S POINT.



HENDERSON'S POINT AS IT LOOKED IMMEDIATELY AFTER THE BLAST.

was removed, the work of putting in the holes began. Eight Ingersoll-Sergeant "H-9" Drills were used. These drills are the largest made, having cylinders 5½ inches in diameter by 8-inch stroke. The formation of the Point was a combination of seamy trap and hard block rock. Veins of quartz were scattered through it at intervals. The drilling was very hard and irregular and required unusually frequent sharpening of steels.

The mounting of these drills was unusual, the conditions being such as to make the use of either tripods or columns impossible. The drills were bolted in a row to a heavy timber frame-work which was loaded down with stone. After a series of holes were bored, the frame-work was moved along. One of the accompanying illustrations shows seven of these drills in a line and gives an idea of the mounting. "X" bits were used for a distance of about 15 feet, after which the drilling was continued to the desired depth with a chisel bit. As already stated, these holes varied in depth from 50 to 80 feet, the final diameter being 2, 2¼ or 2½ inches, depending on the length. The holes were 5 inches in diameter at the start. The shortest time for driving one of the holes was twelve hours. In the case of others, however, it was much longer, the formation of the rock being such that the progress was very slow. Some idea of the service required of these drills can be obtained when it is remembered that the longest drill steels weighed as much as 800 pounds. One of the accompanying illustrations shows one of these steels being carried to the blacksmith shop by a gang of men.

Compressed air was the power selected for operating these drills. The power house was located about 600 feet from the Point and contained three air compressors. Two were of the duplex type with a capacity of 800 cubic feet of free air per minute each. The other was a straight-line compressor of smaller capacity. Air was supplied at 100 pounds pressure at the power house. A 4-inch main carried it to the edge of the excavation where smaller lines took it to the drills and hoists. Of the latter there were twelve which lifted the rock from the hole and placed it in cars. This rock was used for filling in other parts of the Navy Yard.

As the "rim" in some places was low enough to admit water at high tide, it was necessary to build a coffer-dam on top of it. The current was so strong that this was broken on several occasions, thereby flooding the excavation and compelling a temporary cessation of work. On the completion of the drilling, the holes were charged with a special 75 per cent. dynamite supplied by the National Powder Company. This was made in sticks varying in diameter from 1½ to 4 inches. The exploders were wired up by Chief Electrician Thomas F. Flannigan, of the Navy Yard. This required great care, as it was of particular importance that the entire charge should be exploded at the same time.

To break up the coffer-dam, holes were made in it 10 feet apart and each charged with 30 pounds of dynamite. The efforts of the laborers to open a passage in the coffer-dam so that the excavation might be filled before the explosion did not appear successful, so that it became necessary to break a passage in the dam with dynamite. This was accomplished safely without injuring the heavy charge beneath.

A great crowd witnessed the blast which took place at 4.10 o'clock. None of the engineers were certain as to what the result might be and there was a general fear that much damage might be done to both life and property. The water proved to be a very effectual blanket, however, although the water and debris of the coffer-dam were thrown over 100 feet in the air.

The task of removing the broken rock with dredges will begin at once. The contractors report that the blast was very satisfactory in breaking up the Point and the outlying rock.

Mr. O. W. Foster, as superintendent of the Massachusetts Contracting Company, has had charge of the work for the contractors. Lieutenant G. E. Gregory, U. S. N., has been the engineer in charge of the work for the Government.

CHARLES B. MORSE.

Internal Reheating of Compressed Air.*

PART I.

The wide and rapidly increasing application of compressed air makes a successful system of reheating especially desirable. It may safely be said that at the present time there is no good reheater on the market. When it is considered that in many cases the well known advantages to be obtained by reheating are sufficient to make profitable a system of air transmission or distribution, which would otherwise be infeasible, it must be conceded that the problem of reheating is well worth investigating.

Air possesses several properties which fit it peculiarly for use in many kinds of service where other media would be at a disadvantage. As compared with steam it permits of transmission to long distances without serious loss of power, or danger of accident. It may be distributed to widely scattered tubes in bare pipes running on top of the ground. For temporary work such as excavating, tunneling, quarrying, etc., its advantages over steam are obvious. In mining it has obtained a wide application owing to its convenience and safety. Another strong advantage of compressed air for transmitting power, is that the work lost in friction and other losses may be largely regained by reheating the air close to the point of use. In this way the original power used in the compressor might be equalled or even exceeded at the expense, of course, of a certain amount of fuel, but the fuel so used is utilized more efficiently than in almost any other known method of transforming heat into work, as will be shown later.

We wish, however, to make it clear that we are not considering the use of this system as a method of power development, or in other words, as a "constant pressure heat engine." We are aware that many losses attend the use of compressed air and do not anticipate any profit from compressing air simply for the purpose of adding heat to it and transforming this heat into work. But we do believe, however, that compressed air has advantages which have caused it to be used extensively in spite of losses in its use, and what we wish to emphasize is the desirability of using air with as great economy as possible if it is to be used at all.

Economy of compression has reached a high degree of perfection, little can be done to improve this end of the system. Losses in transmission in a well designed system are very small. The only way left to increase the economy is at the point of use and this can be done most effectively with any kind of tool or motor by reheating the air if conditions permit.

Methods of Reheating.—The methods used or proposed for reheating compressed air may be classified as "External" and "Internal" and again as "Wet" or "Dry."

By external heating we mean transmission of heat from a source on one side of a metal wall to air on the other side. By internal heating we mean the addition of heat within the air itself.

Wet heating may be applied to cases in which the air comes into intimate contact and mixture with steam or hot water.

Dry heating will designate those methods in which water or steam is not mixed with the air. These methods may be tabulated as follows:

I.—External Heating.
- (a) Heat transmitted to the air from a fire or a current of hot gases through pipes or metal walls.
- (b) Heat transmitted to the air from hot water or steam through pipes or metal walls.

II.—Internal Heating.
- (c) Heat developed by combustion of fuel under pressure in the air itself or in a part of it.
- (d) Heat added by injecting a quantity of superheated air or products of combustion into the current of air.
- (e) Heat added by injecting steam into the current of air.
- (f) Heat added by injecting hot water into the current of air.
- (g) Heat added by passing the air through a tank of superheated water.
- (h) Heat added by passing of an electric current through a resistance surrounded by the current of air.

Of the above methods the following are dry heating (a), (b), (c), (d) and (h). The theory of these different methods of dry heating is practically identical; methods (a), (b) and (h) are exact equivalents as far as their results are concerned; methods (c) and (d) are modified slightly by the change in chemical composition of the mixture of the air and gas due to the combustion. In the burning of carbon one volume of oxygen is burned

* Thesis presented by C. A. Dawley and A. W. Stone for the degree of M. E. at Cornell University, June, 1904. Published in the January and February (1905) issues of the *Sibley Journal of Engineering*. Cuts used through the courtesy of that publication. Part II. will appear in September COMPRESSED AIR.

forming one volume of carbon dioxide, in burning hydrogen the product of combustion is steam and the volume may be slightly changed. The amount of hydrogen in any fuel which would be used is so small as to make this fact of no significance from a practical standpoint. Hence we may consider all the five methods of dry reheating as identical from a thermodynamic standpoint.

Theory of Dry Reheating.—The compression of air as ordinarily performed in an air compressor is nearly an adiabatic process. All of the work spent in compressing the air is transformed into sensible heat which raises the temperature of the air. A slight portion of this heat is abstracted by the cylinder walls, but experience has shown that this effect is not large. We may consider the process as adiabatic without serious error.

If now the air so compressed is admitted without loss of temperature to an expansion cylinder without clearance and of the same size as the compression cylinder, it will trace a card identical with the compression card and the efficiency of transmission, disregarding other sources of loss, will be unity. In all actual cases, however, the air loses most of the heat of compression before being admitted to the working cylinder. The specific heat being low it is impossible to transmit air to any considerable distance without having it reduced nearly to the temperature of the surroundings of the pipe which carries it.

The work which will be done by air in any kind of motor is directly proportional to the volume of the air supplied, and this in turn is directly proportional to the absolute temperature.

For example, if air is received at 60 F.

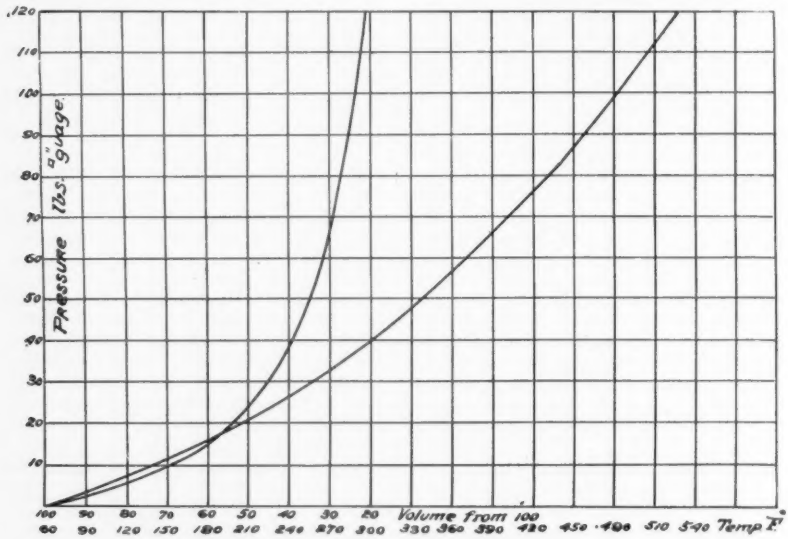


FIG. I.

and this reheated to 400 F. it will increase in volume $\frac{400+460}{60+460} = 1.652$ times its volume as received. This means that the same air will do 65 per cent. more work when reheated, or that the same work can be done for $\frac{1}{1.652} = 60.5$ per cent. as much heated air as would be required if the air were used cold. Another feature of this apparent advantage is that the actual gain is almost invariably greater than the theoretical. This unusual fact is due to the better lubrication, freedom from freezing and consequent higher mechanical efficiency with heated air. In an extended trial of a 10 H. P. piston engine used as an air motor, in the Popp compressed air

system in Paris, Prof. A. B. W. Kennedy found that, with an increase of the admission temperature from 83 F. to 315 F., the mechanical efficiency rose from 67 to 81 per cent.

Reheating is generally intended to bring the air to about the same temperature at which it left the compressor. This temperature will depend upon the initial temperature of the free air used and upon the ratio of compression. The curve in Figure 1 shows the temperature of air compressed adiabatically from 14.7 pounds and 60 F. to various final pressures. This assumes no abstraction of heat during compression, *i. e.*, that the temperature increases according to the law

$$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{.29}$$

It will be noted that the temperature of the air reaches 400 F. at about 70 pounds gauge pressure.

It has been generally assumed that dry air for use in machinery should not exceed 400 F. at admission. Hence for single stage compression and reheating before use, of air at 70 pounds pressure, we should obtain the same power in the motor as was expended in the compressor, neglecting all other sources of loss.

It is possible, however, to compress air more economically in two or more stages with intermediate coolers or even in some special cases to secure isothermal compression as in the Frizell system used in the Taylor hydraulic compressor.*

In these cases the heating of the air is not strictly speaking a "reheating," but it offers the same economy in the application of the air in connection with the additional saving in compression.

It is a simple matter to compute the work efficiency of the fuel used in reheating for a perfect case, that is, for a motor without clearance, and cutting off at such a point as to secure complete expansion. It may also be computed for any assumed conditions of pressure, clearance and ratio of expansion. Some typical cases are worked out in this manner below. It should always be remembered, however, that the ultimate basis of comparison is the relative amount of power that will be produced by a pound of fuel at the heater, as compared with the power produced in compressed air by a pound of fuel burned under a boiler, in case the compressor is run by steam. For a compressor run by water or other power the cost per unit of power produced by the heater and of that produced by the prime mover are the items to be compared. It will usually be found that it is not essential to know the exact thermal efficiency of the heat applied in reheating, since it is true that when conditions permit of reheating it will pay to do it.

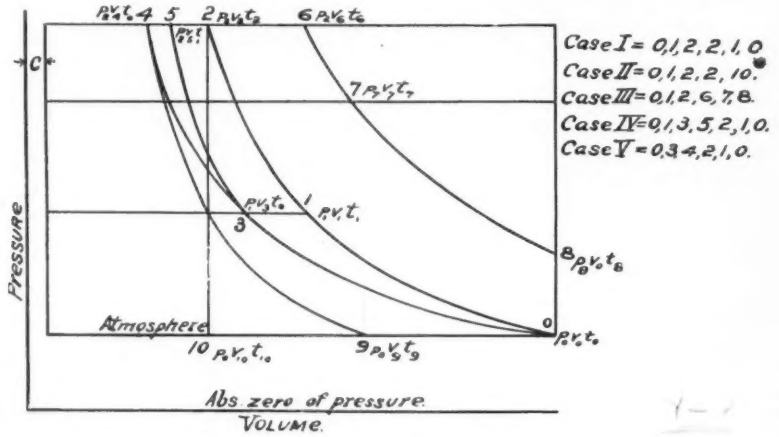

Case I = 0, 1, 2, 2, 1, 0
Case II = 0, 1, 2, 2, 10.
Case III = 0, 1, 2, 6, 7, 8.
Case IV = 0, 1, 3, 5, 2, 1, 0.
Case V = 0, 3, 4, 2, 1, 0.
Pressure
Atmosphere
Abs. zero of pressure.
Volume.

FIG. 2.

* See W. O. Webber, A. S. M. E., May, 1901.

In the illustrative examples below, case I is an ideal case; case II corresponds to most pneumatic tools, rock drills, direct-acting pumps and other machines using air non-expansively; case III is approximately that of a slide-valve engine such as might be used for a hoisting engine; case IV is for a two-stage compressor and single-stage motor and case V is for a hydraulic compressor which gives isothermal compression, and a motor giving complete expansion in one stage. This last case is of course the most favorable and is not unattainable in practice.

Figure II shows these various cycles, together with some others. Of course, these cases are quite theoretical and to be reduced to practice we must take into account the various losses by friction, incomplete expansion, throttling, back pressure, etc. It may be noted in this connection that air, on account of its permanence of state and its poor heat-conducting properties, does not suffer the serious losses due to condensation and heat interchanges as does steam. In fact with a motor designed to operate under known conditions, the indicated work bears a very high ratio to the computed; as high as 90 per cent. to 95 per cent.

In all the cases considered we assume 1 pound of air initially at 14.7 pounds abs., and 60 F., volume 13.3 cubic feet.

Case I.—Adiabatic compression to 70 pounds abs. Cooled in transmission to the initial temperature. Expanded completely in motor without clearance. Reheated before use to the temperature of compression.

The work of compression is

$$W=3.463\ P_0\ V_0\left[\left(\frac{P_2}{P_0}\right)^{.29}-1\right]$$

$$W=3.463\times 14.7\times 144\times 13.1\times\left(\frac{70}{14.7}\right)^{.29}-1$$

$$=54,890 \text{ ft. lbs.}$$

Temperature at end of compression is

$$\frac{T_2}{T_0}=\left(\frac{P_2}{P_0}\right)^{.29}=1.572,$$

$T_2=(60+460)\times 1.572=819°$ abs. $=359°$ $F.$

Air cools to 60° and is reheated to 359°. Rise of temperature is 359°—60°=299°.

Heat required is $299\times .2375=71$ B.T.U.

The work of expansion is the same as the work of compression. If the air had been used cold the work of expansion would be reduced in the same ratio as the absolute temperature of admission.

$$W_1=\frac{520}{819}\times 54,890=34,800 \text{ ft. lbs.}$$

Gain by reheating $=54,890-34,800=20,090$.

$$\text{Thermal efficiency of reheat}=\frac{20,090}{71\times 778}$$

$$=36.5\%=e$$

Case II.—Same as case I, except that the air is used non-expansively in a cylinder having 10 per cent. clearance. Volume of the compressed air after cooling $=13.1\times\frac{14.7}{70}=2.75$

Work if used cold,

$$W_1=\frac{100}{110}\times 70\times 144\times 2.75-(14.7\times 144\times 2.75$$

$$=19,360 \text{ ft. lbs.}$$

Work if reheated to compression temperature:

$$W=\frac{819}{520}\times 19,360=30,450 \text{ ft. lbs.}$$

Gain by reheating $30,450-19,360$
$=11,090$ ft. lbs.

$$e=\frac{11,090}{71\times 778}=20.05\%$$

Case III.—Same as case I, except that air is cut off at 45 per cent. stroke and expanded in a cylinder having 10 per cent. clearance.

Volume at C.O. $=45+10=55$.

Volume release $=100+10=110$. Ratio of expansion $=2$.

If used cold, $V=2.75$ cubic feet at 70 pounds. The work may be computed in three parts, viz.: work of admission $=W_a$; work of expansion $=W_e$, and negative work during exhaust $=W_b$.

$$W_a=\frac{45}{55}\times(2.75\times 70\times 144)=22,660 \text{ ft. lbs.}$$

$$pv^{1.41}=c=p_2\,v_e^{1.41}=70\times 144\times(2.75)^{1.41}$$

$$=42,000$$

$$W_e=\int p.\ dv.=c\int\frac{1}{v^{1.41}}dv=\left[\frac{c}{-.41}(v)^{-.41}\right]_{2.75}^{5.5}$$

$$=\frac{42,000}{-.41}\left[\frac{1}{(5.5)^{.41}}-\frac{1}{(2.75)^{.41}}\right]=16,680 \text{ ft. lbs.}$$

$W_b=14.7\times 144\times 5.5=11,640$ ft. lbs.

$W_1=22,660+16,680-11,640=27,700$ ft. lbs.

If used hot, $W=\frac{819}{520}\times 27,700=43,600$ ft. lbs.

Gain $=43,600-27,700=15,900$ ft. lbs.

$$e=\frac{15,900}{71\times 778}=28.8\%$$

CASE IV.—Two-stage compression to 120 pounds absolute with intercooling to initial temperature. Reheat to temperature which would have been produced by single-stage compression to 120 pounds. Expand completely in single-stage motor.

It may be shown that the work of compression is a minimum when an equal amount of work is done in each cylinder, and that this will occur if the ratio of compression (r) in the first stage is the square root of the total ratio (R).

$$R=\frac{120}{14.7}=8.16 \quad r=\sqrt{8.16}=2.86$$

$$P_1=r\,P_0=2.86\times 14.7=42 \text{ lbs.}$$

$$W_{\text{L.P.}}=3.463\,P_0v_0\left[\left(\frac{P_1}{P_0}\right)^{.29}-1\right]=$$

$$3.463\times 2116\times 13.1\times .356=34{,}200 \text{ ft. lbs.}$$

Total work of compression $=2\times 34{,}200=64{,}400$ ft. lbs.

$$\frac{T_1}{T_0}=\left(\frac{P_1}{P_0}\right)^{.29}=1.356 \quad T_1=1.356\times 520^\circ=705^\circ$$

at end of first and second stages. Similarly if compression were in one stage the temperature at end of compression would be 956° abs. = 496° F.

Work of expansion if used hot:

$$W=3.463\,P_0v_0\left[\left(\frac{P_2}{P_0}\right)^{.29}-1\right]=80\,500 \text{ ft. lbs.}$$

If used cold:

$$W_1=\frac{520}{956}\times 80{,}500=43{,}700 \text{ ft. lbs.}$$

Gain by reheating $=36{,}800$ ft. lbs.

$$e=\frac{36{,}800}{103.8\times 778}=45.6\%$$

CASE V.—Isothermal compression to 120 lbs. abs. Expansion as in case IV. Work of compression $=\int pdv+p_2v_4-p_0v_0$

$$pv=c=2116\times 13.1=27{,}700.$$

$$\int pdv=c\int\frac{1}{v}dv.=c\log_e\left(\frac{v_0}{v_4}\right)=c\log_e\left(\frac{p_2}{p_1}\right)$$

$$=58{,}050 \text{ ft. lbs.}$$

$$W_c=58{,}050\ (120\times 144)\times\left(13.1\times\frac{14.7}{120}\right)-$$

$$(2116\times 13.1)=58{,}050 \text{ ft. lbs.}$$

The work of expansion for both cold and heated air is the same as in case IV.

$$e=\frac{36{,}800}{103.8\times 778}=45.6\%$$

It may be noted that for convenience the degree of reheat in all the above cases is considered to be that corresponding to the adiabatic compression of the air to the maximum pressure. The same efficiency would be obtained in each case for any other amount of heat added, as the work performed in any case is directly proportional to the absolute temperature.

The above takes account only of the thermal efficiency of the heat actually put into the air. We may make a more practical comparison by assuming an efficiency for the reheater and a coal consumption per air H. P. at the compressor.

In the tabular comparison we have assumed four pounds of fuel of 14,000 B.T.U. per pound to be required per air H. P., and show results for an ordinary external heater of 60 per cent. and an internal heater of 95 per cent. efficiency.

Wet Heating.—A complete theory of heating by methods (e), (f) and (g) might be developed, but it would be exceedingly cumbersome in its application, and probably of little practical value. We shall consequently confine ourselves to a brief comparison of different ways of wet reheating. Method (e) is the one which is perhaps most desirable and which is in actual use in at least one large installation, viz.: the compressed air transmission

	I.	II.	III.	IV.	V.
1. Work of compression.	54890	54890	54890	64400	58050
2. Work expansion if cold	34800	19860	27700	43700	43700
3. Work if reheated.	54890	30450	43600	80500	80500
4. Gain by heating	20090	11090	15900	36800	36800
5. Heat units required	71	71	71	103.8	103 8
6. Efficiency of reheat	36.5	20.05	28.8	45.6	45.6
7. Ratio 2) to (1)	.634	.353	.505	.680	.753
8. Ratio (3) to (1)	1.	.555	.795	1.25	1.39
9. Ratio (4) to (1)	.366	.202	.29	.571	.634
10. Ratio (3) to (2)	1.57	1.57	1.57	1.84	1.84
Efficiency of fuel used in heater as compared with that used in boiler—					
11. With external heater.	4 81	2.65	3.80	6 01	6.01
12. With internal heater.	7 62	4 18	6.01	9.52	9.52

at Chapin Mines, Iron Mountain, Mich., where 2,000 H. P. in compressed air is transmitted 3½ miles and utilized in engines for electrical generation, hoisting and general power purposes, and in pumps, rock drills, etc. They have steam available at the mines, and their practice is to turn steam into the air line near where the air is used. The result is to reheat the air to a moderate extent and also by condensation of the steam on the expansion

stroke, to prevent freezing in the exhaust. On mixing with the air, which is at atmospheric temperature, a quantity of steam is condensed sufficient to heat the air up to the temperature of the steam. This will not be the temperature corresponding to the steam before admission but that corresponding to the part of the total pressure in the air line which is due to the steam. By increasing the amount of steam this temperature may run up to 200 or 250 F. or even more, but the general practice is to use only enough steam to prevent freezing in the exhaust. After an equilibrium of temperature is reached, the mixture of air, steam and hot water passes into the cylinder and after cut off expands as usual except that the air tends to fall in temperature much more rapidly than the steam. This causes the steam to continue to condense thus giving up its latent heat and part of the heat of the liquid. The result of this is that the steam itself does less work than if expanding alone, and the air does more work by reason of its fall of pressure being retarded by the heat surrendered by the steam. The net result might easily be computed but may better be determined by experiment, and some tests with this object were conducted by the writers, and the results will follow later.

Mr. Edward A. Rix gives the following table of the amount of steam required to prevent freezing of air at complete expansion at 212° F.

Gauge Pressure.	B. T. U. per Pound of Air.	Pounds of Steam per Pound of Air.
70	59	.051
80	62.8	.055
90	66.2	.059
100	69.2	.0604

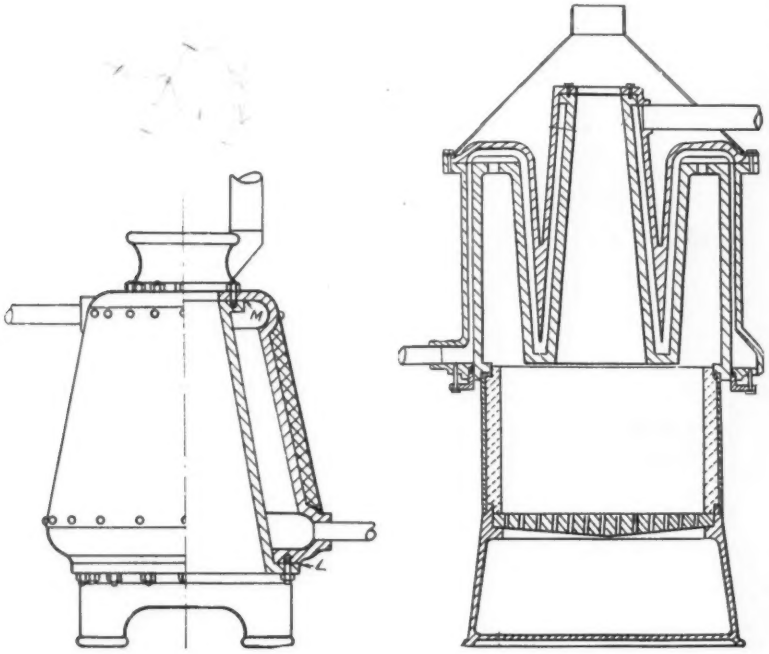
Hot Water Reheating.—Method (f) is similar to (e), but in this case a larger amount of moisture is required than for steam and the method would not be adapted to give any material degree of reheat more than enough to prevent freezing.

Mekarski System of Reheating.—Method (g) proposed by Mekarski and used by him in compressed air street car service has some advantages for high-pressure air storage systems for self-propelled vehicles. The air is caused to bubble up through a tank of superheated water. This heats the air to the temperature of the water and also saturates it with steam, the amount of which depends upon the volume of the air and the temperature of the water. The difficulty with the arrangement is that the temperature of the water continuously decreases and it must be recharged at intervals. The system, however, proved quite successful for this class of work.

Summing up the case for wet and dry reheating we may say that wet heating is a makeshift which is better than none, and which should be employed in cases when dry heating is not permissible. It does not, in any of the methods noted, give a high degree of reheat nor is all the heat supplied used to the best advantage. The best approximation is in the Mekarski system provided the water is kept sufficiently hot. A small amount of moisture in the air is no doubt beneficial to the machinery using it, as it would assist in lubrication and prevent to some extent the deterioration of the oil which is likely to occur with very hot dry air. Dry heating offers the highest thermal gains and may be carried as high as is desired by methods (a), (c), (d) and (h). In method (b) the temperature is limited to that of steam at permissible pressures. As regards external or internal methods of dry reheating it may be said that the only thermal difference of importance is the efficiency with which the heat supplied is put into the air. With external heating we have of necessity a large flue loss, so that, of the heat contained in the fuel, not over 50 per cent. to 60 per cent. may be expected to appear in the air. With internal heating by methods (c), (d) and (h) the only necessary loss is radiation which may be reduced to a negligible quantity. The points which must be considered in determining the desirability of internal and external heating are: (1) Constructional features of the heaters. (2) Relative regulation of temperature with varying demand for air. (3) Danger to the machinery from excessive heat or dust. (4) Simplicity of operation and attendance required. In order to consider these points intelligently a brief description is given of the leading types of heaters now in use. Combustion heaters of the external type are composed either of a series of pipes or coils or of cast-iron shells having a jacket space for the air to pass through and a fire pot for holding the combustible. Pipe heaters have not been successful except for very moderate temperatures or when the flow of air is uniform. The

condition is similar to that of a steam superheater, but worse, as air has less heat capacity than steam. In case the air is shut off for a short time the pipes become redhot and their life under these conditions is very short. Cast iron is the only metal which will stand the action of heat without rapid deterioration. The form of cast-iron heaters has been, as stated above, a shell or stove with an angular space for the air to pass through. In any such arrangement we have an outer wall and an inner wall, one of which is exposed to relatively cold air and the other to a hot fire. The heater may be made in small sizes in one casting with the jacket space cored out. If these are carefully designed and not allowed to get too hot they will stand all right, but if these conditions are not met, they are quite likely to rack on account of the large temperature strain. For any except small sizes the heater must be made of an outer and an inner casting. Figure 3 shows sectional views through the two leading makes of heaters of this class.

The Sergeant heater has the two shells rigidly connected together by studs and the joints packed with asbestos gaskets. The design is such that as the inner casting heats and expands, the joint (*M*) is forced more tightly together while the joint (*L*) tends to come open. In using a heater of this make at Sibley College the writers found, as had some previous experimenters, that it was extremely difficult to keep the joint (*L*) tight when the heater was well warmed up.



SERGEANT HEATER. FIG. 3. RAND REHEATER.

In the Rand heater this difficulty is met by providing an expansion joint with packing and a stuffing ring as shown. In this case the expansion strains are avoided at the expense of a rather clumsy arrangement and complicated castings, and there is still a joint which has a strong tendency to develop leakage.

A number of internal reheaters have been proposed, although only one (the

Edison) has gone farther than the Patent Office. In the Park reheater illustrated in Figure 4 the inventor proposes to divide a current of air, passing a part of it through a coal fire on the grate 6 and by-passing the remainder through the pipe 12. The cold air mixes with the products of combustion which come through the pipe 4 into the mixing chamber and the mixture passes out through 14 to the engine. The thermostatic tube 15 controls the double seat valve 13, which sends more or less of the air through the fire according to whether the mixture is too cold or too hot. This provides a construction free from temperature stresses and also gives an automatic regulation to the temperature. The fuel consumed and the heat developed will be proportional to the air used. Thereby an important advantage over the external heaters is obtained, viz: the device is self-regulating. However, it needs little argument to show that the air from this heater would not be safe to use in any sort of cylinder and piston as the ash and dust from the solid fuel will be carried along in the air and rapidly cut out the machinery. Also there is a strong possibility of the regulation of temperature being erratic and the heat becoming intense enough to do serious damage.

In the Edison reheater an improvement on the Park is the addition of a jacket through which the main part of the air is lead and heated by radiation from the inner shell. This, however, brings the same difficulty from expansion as the external heater. There is a joint exposed to the full pressure of the air and to the action of high temperature. Edison does not use any thermostatic regulator because the device is approximately self-regulating, as the flow of air through the fire will be proportional to the demand for air on the outlet. It is readily seen that the difficulty from ash and dust remains as with the Park heater, also that there is in this heater a possibility of excessive temperature at times. This heater has been quite extensively experimented with by the Ingersoll-Sergeant Drill Company. Their chief engineer, Mr. Prellwitz, states

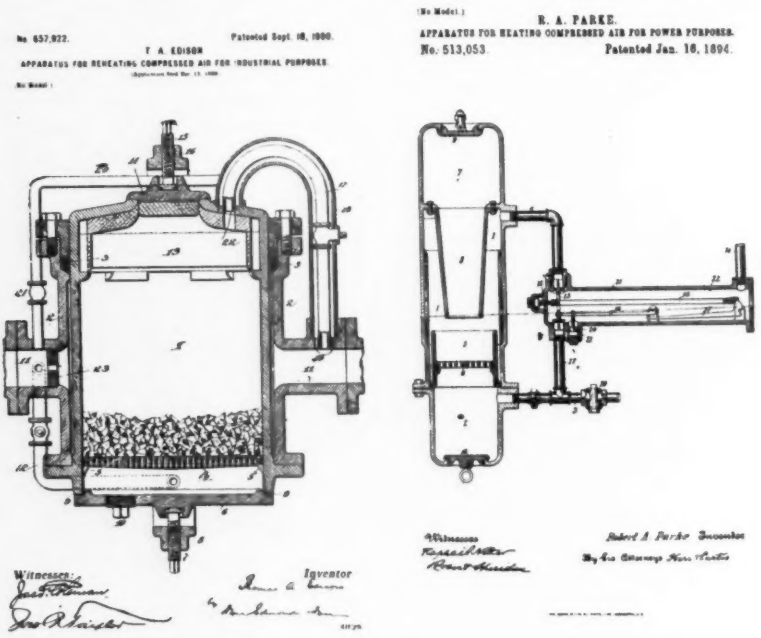


FIG 4.

that there is no difficulty in heating the air and that the heating is done with remarkably little fuel but that the air has not been safe to use on account of dust and ash. By fitting separators to the delivery pipe the most of this can be deposited and some of these reheaters have already been put into commercial use. Different kinds of fuel, charcoal, coke, hard and soft coal have been used, all with the same result.

Summing up the case for these various heaters we may state: (1) The constructional features of all external heaters are bad. (2) Regulation of temperature in external heaters is entirely lacking with a variable demand for air. (3) The internal heaters described are dangerous to machinery on account of dirt in the air. (4) The external heater is slightly more convenient to operate as the fire is not under pressure.

In the second section of this article a heater proposed and built by the writers in which the above defects are eliminated will be described.

(*To be continued.*)

Air Power in the Quarry.*

Compressed air as a mode of applying power is no novelty. Certain of its advantages have long been known and generally acknowledged. For instance, in mines and tunnels and in other confined places, where steam is prohibited by unendurable steam pipes and stifling exhaust, air under pressure has been almost unanimously accepted as the only agent meeting the arduous conditions of service. But even with these points of superiority, all its adherents know that these advantages are gained only at high expense. The rock drill has never been regarded as an efficient air engine; but it is known and loved for its tremendous faculty of "getting there." The air-driven hoisting engine was considered merely a necessary evil; it was tolerated because it seemed to be the only means of accomplishing certain ends, but it was disliked because of its voracious appetite for air. In cases where efficiency was less important than expediency, results alone counted.

It must be confessed by the pneumatic engineer of those earlier days that the charge of poor economy was not without foundation in fact. Be it further confessed that the average air-power plant will not weigh up well in the scale of efficiency, even in this era of economic refinement. In earlier times justifiable ignorance gave full explanation; but in the air plant of to-day nothing but the most inexcusable carelessness can account for low economy. Now, it is not fair to charge a system with defects which are due to poor engineering and bad management; it is the purpose of this paper to show that such charges, if not wholly unfounded, are at least unjustified as against the power system itself. Compressed air can be, and is being, used with a high degree of economy and widely diverse in fields. To-day its usefulness is not limited to localities where nothing else can be used; on the contrary, it is holding its own in fair and open competition with other powers. Indeed, there are certain avenues of activity in which compressed air should properly have no competitor whatever; one of the most important of these is the modern stone quarry.

Time was when "anything was good enough for the quarry," as it had been for the mine. The main thing was to "get out the rock." Cost-keeping method was crude and the market was easy, and profits came in spite of carelessness. But in this day of competition the secret of success in stone quarrying hinges on reducing the cost of production to the lowest limit. The successful quarry organization of to-day is a huge machine adapted to secure maximum output at minimum cost.

Power is fundamental in every modern productive organism. Power costs often comprise a large factor of total productive costs. But more far-reaching in the method of production is the influence of a suitable power. This is true, whether the productive organism be a machine shop or a quarry. Increased production may be desirable, even though the method which secures it may not reduce the power charge. But if the adoption of a new power system should result in an increase in production, together with a lowering of cost, in the hands of the aggressive manager, it becomes a two-edged sword entering a hotly contested field. In the paragraphs following it will be shown that compressed air does accomplish this. But as mere statements of possible economy, unsupported by indubitable fact, may

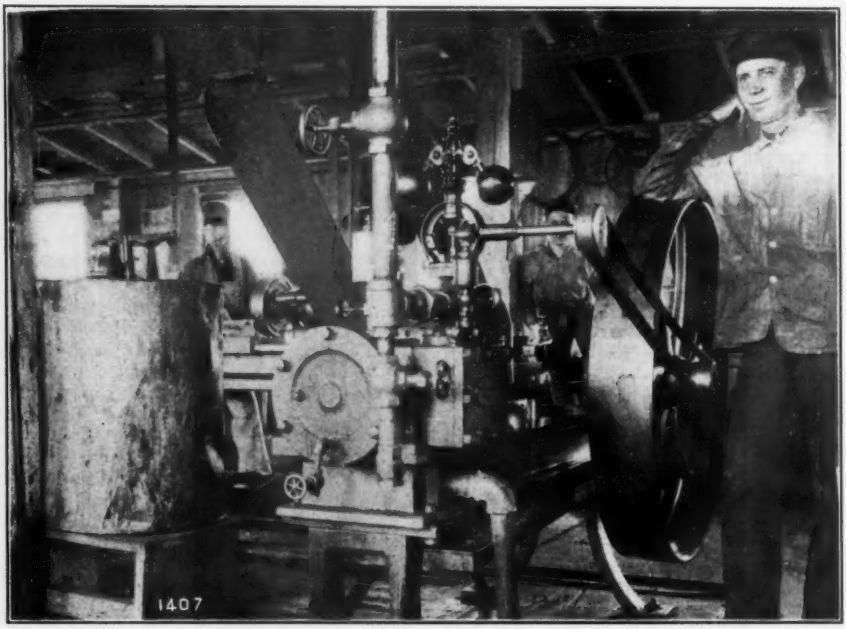
*By Mr. Lucius I. Wightman, in the *Engineering and Mining Journal.*

awaken incredulity, I shall sketch briefly a conspicuous example of the central compressed-air quarry plant.

The Gray Cañon Quarry of the Cleveland Stone Company, at North Amherst, Ohio, is the largest sandstone quarry in the world. It is a chasm 165 feet deep and more than a mile in circumference—a "cañon," indeed. It has been a stone producer for generations. Its output is wholly in dimension stone—a gray sandstone for building purposes and a fine-grained quality for grindstone stock. The equipment provides not only for the quarrying, but also for the cutting of stone to finished size.

For years the property was operated under the usual quarry method. Steam-driven mills, pumps and hoists were supplied from scattered boiler plants; channelers and drills drew their steam from a host of small portable boilers, and over all brooded the darkness of vapor and smoke. The introduction of steam marked a great advance over the old hand method, and the new system was hailed as the guardian spirit of the Gray Cañon. But the quarry grew, boundaries extended, depth increased. As conditions changed with growth, the shortcomings and the limitations of steam power became apparent.

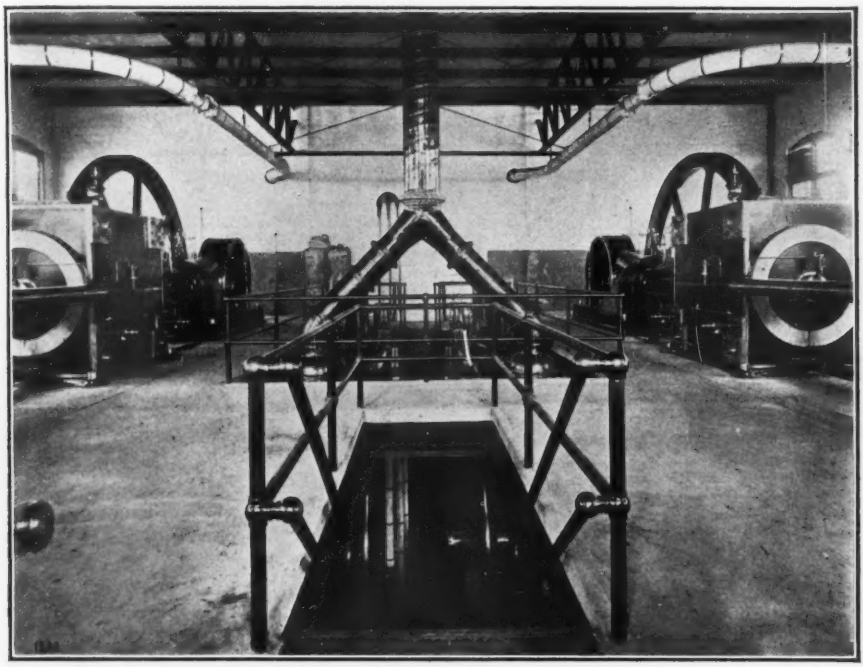
The small-boiler plants were expensive steam generators; their appetite for coal was unreasonable. The distribution of fuel to the scattered boilers added cartage to the cost per ton; much was lost in transit, and in the continual moving of the portable plants. The result of these combined conditions was a fuel consumption, per pound of steam generated, that was startling. Added to this was the enormous steam consumption. It was impracticable, if not wholly impossible, to protect the steam lines, and pipe condensation was heavy. As the quarry grew and as pipe lines lengthened, this condensation increased in a still greater ratio; it was found that the major portion of the steam



A 20 HORSE-POWER SLIDE-VALVE ENGINE, OPERATED BY COMPRESSED AIR, RUNNING THE MACHINE SHOP.

generated never reached the engines. Inevitable results of this excessive condensation were a serious drop in pressure, and very wet steam; and these evils were exaggerated in engines which were not designed primarily for high economy. It was found that the machines, under the action of wet and sluggish steam, were doing only a fraction of the work expected. All these conditions combined to produce an appalling steam consumption which was rendered still more discouraging by the heavy fuel cost. To these measurable quantities were to be added certain less tangible losses, as the cost of labor applied in boiler attendance and repair, and in the maintenance of pipe lines; the draining and thawing of pipes in cold weather; the labor and time consumed in moving portable plants; the shortening of the working day by the murky cloud in the quarry; the loss of time in starting at morning and noon; and, most subtle of all, the demoralizing effect of the smoke and steam on the temper and efficiency of the quarry workmen. These evils resulted in menacing the very existence of the Gray Cañon.

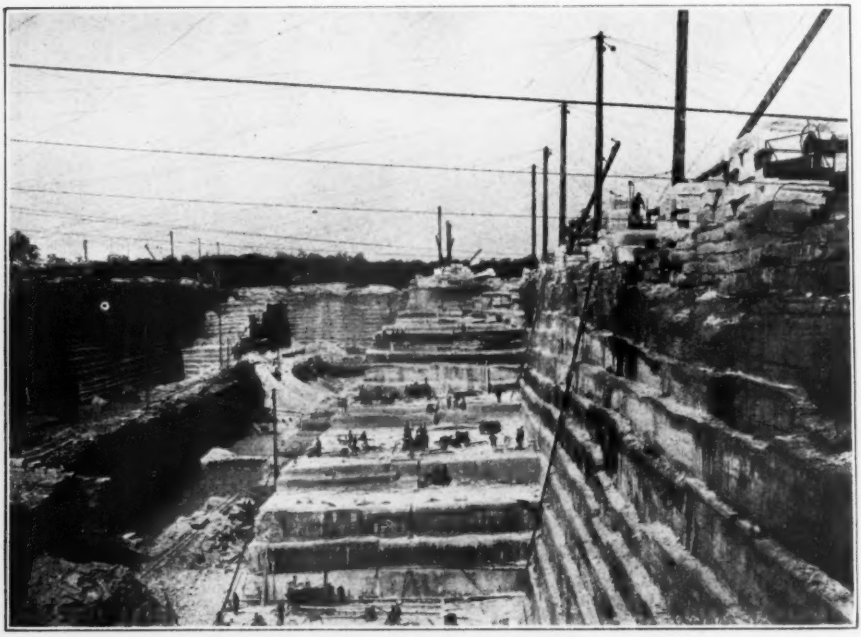
As a crisis seemed near, the management looked around for a remedy.. After scanning every possibility, they finally entrusted the problem to the engineers of the Ingersoll-Sergeant Drill Company. Compressed air was decided upon. A strong advantage of the use of air power was that it could be applied effectively and cheaply to the quarry machinery already in use with steam. The old steam plant at the Gray Cañon included thirty-one isolated boilers (aggregating 1,200 boiler horse power), many miles of small steam pipe, and a multitude of mill and shop engines, hoisting engines, channeling machines, drills and pumps. It was desirable, if not absolutely essential, to retain in service as much as possible of the old



INTERIOR OF THE POWER HOUSE, SHOWING THE JET CONDENSERS AND AIR PUMPS.

equipment. The plan contemplated a central air-compressing plant, a system of air-pipe distribution, and an application to machines already in use.

The power plant installed is centrally located and represents the highest attainment in steam and pneumatic practice. No point has been neglected which would contribute to plant economy. Steam is generated at 180 pounds pressure in four water-tube boilers, equipped with mechanical stokers and induced draft, and aggregating a trifle over 1,000 boiler horse power. As originally installed, for the Gray Cañon alone, only three of these boilers were in place; the fourth was added when extra load came upon the system. Feed and circulating pumps—in fact, all auxiliaries—are of standard types. Two air-compressing units are installed; they are steam-driven cross-compound-condensing two-stage Corliss machines, with positive air-thrown air valves. At a rate of speed of 90 revolutions per minute, with air at 100 pounds pressure and steam at 165 pounds, each unit indicates about 1,000 horse power and has a piston displacement of 6,030 cubic feet of free air per minute. Compound steam-driven jet condensers handle the engine exhaust, drawing condensing water from an extensive system of cooling trays outside the power house. Reheating steam receivers, between high and low-pressure steam cylinders of the main units, receive also the exhaust from the condenser engines. Air cylinders are completely water-jacketed; inter-coolers and after-coolers are introduced at proper stages. The power plant in every detail is designed to secure minimum cost.

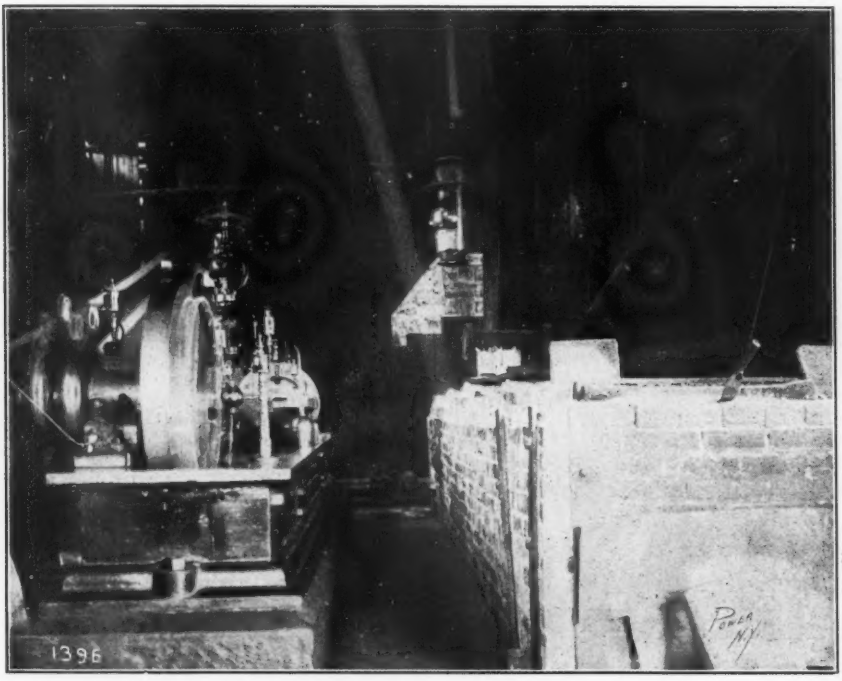


VIEW OF THE GRAY CANON QUARRY AS IT LOOKS SINCE THE INSTALLATION OF THE CENTRAL COMPRESSED AIR POWER PLANT.

From the main primary receiver just outside the power house a loop system of air-pipe distribution covers the entire workings of the Gray Cañon. Without going into detail, let it be said that this five-loop system secures great carrying capacity at low cost, avoids any measurable

drop in pressure, gives the maximum discharge without drop on any branch, and permits the repair or alteration of any section without crippling or affecting the remainder of the system. It is a scheme of great flexibility. Frequent offsets properly care for expansion and contraction; proper supports relieve the lines from sagging strains. Ample provision is made, by tees and valves, for the attachment of new branches as the active zone shifts about. The work is so carefully laid out and adjusted that the loop system, as a whole, holds its working pressure for 12 hours.

As already stated, the plans called for the continued use, so far as possible, of the old appliances under the new system. The old machines were overhauled and connected; they took up the new burden without a murmur. At the outset, reheating was not contemplated, and the plant was successfully operated for some months on cold air. But the possibilities of reheating were too alluring; now reheaters, simple, inexpensive, and "home-made," are employed at mill engines, hoists and pumps. At present about 300 degrees Fahrenheit is the temperature used, but this is not believed to be the limit. On the old steam channelers the boiler has been retained; a small fire on its partly covered grate makes it a combined receiver and reheater; the cost of coke for reheating is a mere bagatelle.



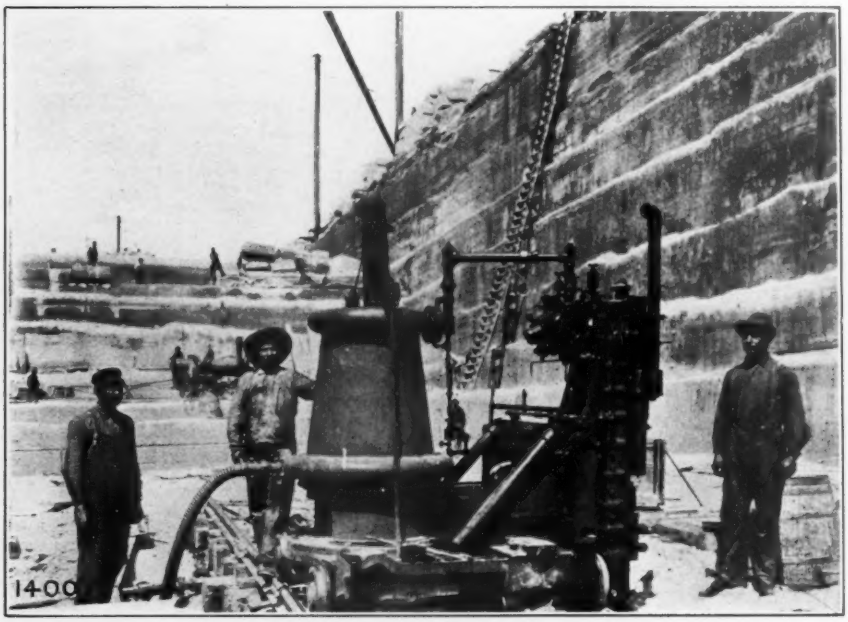
INTERIOR OF MILL NO. 2, SHOWING AN 80 HORSE-POWER ENGINE OPERATED BY COMPRESSED AIR AND DRIVING A FIVE-GANG SAWMILL.

The bane of compressed air in expanding engines has been the freezing at exhaust ports. At the Gray Cañon plant this trouble was anticipated and provided for. A large part of the entrained moisture is condensed and collected in the inter-coolers and after-coolers; another portion finds lodgment in the primary receiver. From this point the lines grade to second-

ary receivers, where the condensation of the entire line is collected and removed through cocks. So perfect is this system for removing moisture that the plant was operated for weeks in freezing weather without reheaters and with no freezing whatever.

The success of the compressed-air plant at the Gray Cañon was so remarkable that two neighboring quarries became interested. Their investigations led to an extension of the air system to the Malone and Mussey quarries, distant, respectively, about 2,000 and 2,200 feet from the power plant. The only addition necessary at the power house was the fourth boiler, already noted, and a second primary receiver from which the new pipe line leads. A novelty was introduced, however, in this new main line and its two branches; instead of standard pipe, steel casing with Hammon joints was used; the cost of the line thus laid was found to be about two-thirds of that of a line of pipe of equivalent capacity. At the Malone and Mussey quarries the air power displaced boilers aggregating 600 boiler horse power, and is applied, as at the Gray Cañon, in mill engines, hoists, channelers, drills and pumps. It will be noted that the present equipment of four boilers, aggregating 1,028 boiler horse power, has replaced 49 isolated boilers, with a combined capacity of 1,800 boiler horse power.

The Gray Cañon plant has been chiefly sketched as an example of compressed-air power applied to quarry work. It remains to consider the results it has accomplished.



A TRACK-CHANNELER USING REHEATED AIR IN THE GRAY CANON QUARRY.

The equipment of the Gray Cañon has been already described. Its success has been phenomenal. The pneumatic engineer may paint a glowing picture, but it is fact and practice which the quarryman wants. The engineers of the Cleveland Stone Company have kindly furnished figures. The table, given herewith, shows the comparative operating costs, averaged per month under the old and the new

forms of power; it shows the number of machines of each kind used, "before and after"; it emphasizes the superior effectiveness of these machines under the influence of compressed air. No attendance is charged against the central station, for the same gang now employed was formerly used in Mill No. 1, which is not listed under the old system.

The figures relating to the Gray Cañon are as found on the records of that property; the Malone and Mussey figures are furnished by the courteous management of those quarries. A striking, and a very significant fact, which does not appear in the table, is this: the output of all these quarries under the new system is largely increased over that under the old scheme, even in the face of these reduced charges.

	1903	April Gray Cañon	June Mussey and Malone	1904	April Gray Cañon	June Mussey and Malone
Coal Consumption	50 tons @ $2.00	$100.00	.....	5½ tons @ $1.60	$24.80	.....
	20 tons @ 2.00	.....	$40.00	10 tons @ 1.60	.....	$16.00
Labor and Attendance at Channelers	16 tons @ 10.00	160.00	.....	12 tons @ 10.00	120.00	.....
	7 tons @ 10.00	.....	70.00	5 tons @ 10.00	.....	50.00
Labor and Attendance at Drills	15 tons @ 3.00	45.00	.....	9 tons @ 3.00	27.00	.....
	6 tons @ 3.00	.....	18.00	4 tons @ 3.00	.....	12.00
Firemen at Hoists	9 tons @ 1.25	11.25	.....	.....	.....	.....
	3 tons @ 1.25	.....	3.75	.....	.....	.....
Firemen at Pumps and Drill Boilers	2 tons @ 1.25	2.50	.....	.....	.....	.....
	2 tons @ 1.25	.....	2.50	.....	.....	.....
Firemen at Mills (12-hour shifts)	2 tons @ 2.00	4.00	.....	.....	.....	.....
	2 tons @ 2.00	.....	4.00	.....	.....	.....
Boiler-Repair Gang	.....	5.00	.....	.....	.....	.....
	.....	.....	2.50	.....	.....	.....
Locomotive Repair and Rental	.....	10.00	.....	.....	.....	.....
Coke for Reheater	.....	.....	.....	.....	1.00	.....
	.....	.....	.....	.....	.....	.50
Total costs per day	.....	337.75	.....	.....	172.80	.....
	.....	.....	140.75	.....	.....	78.50
Total saving per day	.....	164.95	.....	.....	.....	.....
	.....	.....	62.25	.....	.....	.....

Aggregate saving per day..... $227.20
Aggregate saving per year of 300 days.....$68,160.00

The conditions which faced the owners of the Gray Cañon, Malone and Mussey quarries and which led to the installation of the plant just described, are the conditions which, sooner or later, will confront the quarry interests of every stone-producing section. Year by year competition grows keener. Operative conditions become more severe as workings widen and deepen. The demand is for production on an ever-increasing scale. The Gray Cañon plant is simply a pioneer of the quarry plants of the future—it has blazed the path along which development must follow. Compressed air is the hope of the quarryman; in its intelligent application lies the solution of many of his problems.

The basic principles of power-plant design are the same whether the power of the prime mover is to be converted into that of compressed air or of electricity; these principles are too well known to need amplification here. The air compressor must be the basis of an air-power system. The steam-driven compressor is a sturdy, reliable and efficient machine; its efficiency is equal to that of a high-grade steam engine; in fact, the machine itself is simply a high-grade steam engine, coupled to a high-grade compressor by a method which reduces transmission losses to a minimum. Corliss or adjustable cut-off steam ends will give Corliss or adjustable cut-off economy. Properly designed air cylinders give a remarkable compression efficiency. The best compressor builders of to-day guarantee a mechanical efficiency of from 88

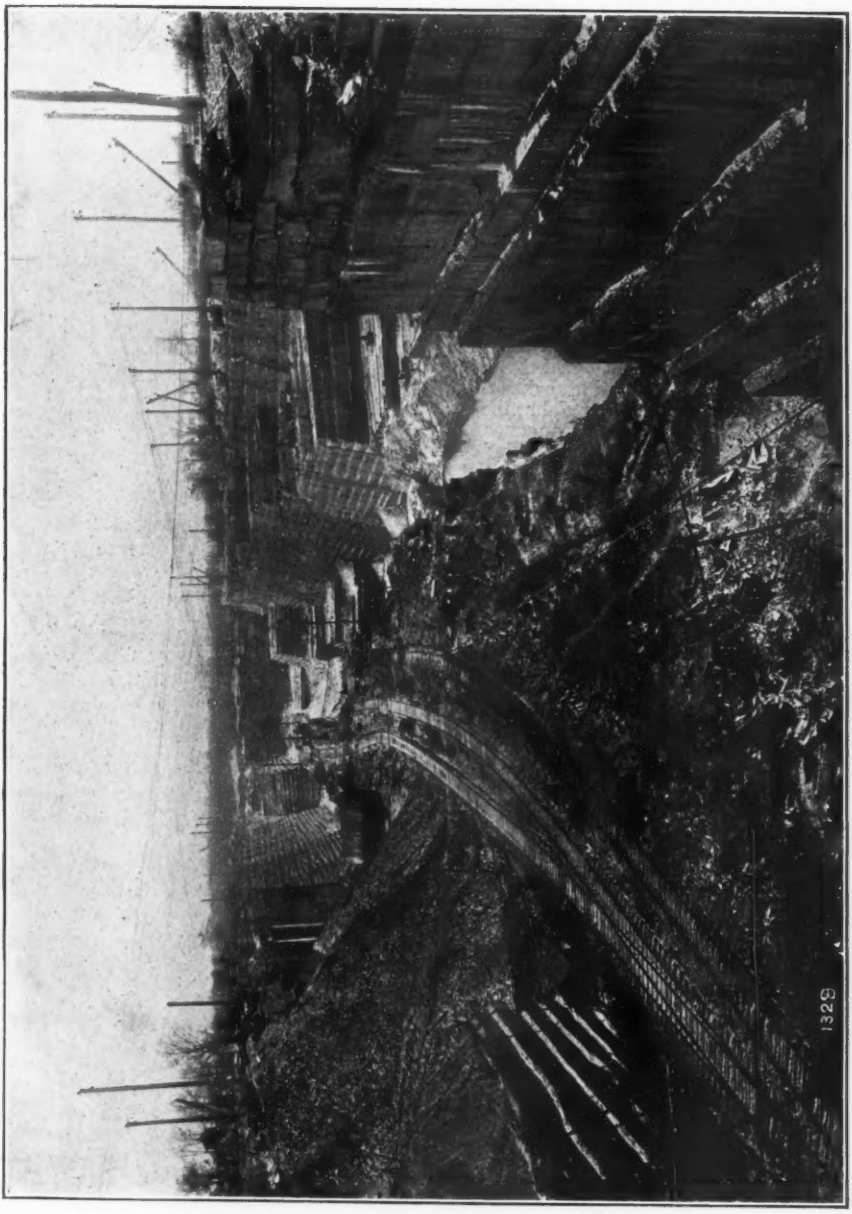
to 92 per cent. in their large machines, a record comparable with that of the best electrical engine units. High-grade boilers assure economy of steam generation. The true measure of plant efficiency is the fuel consumption per unit of power produced; in electrical plants, per kilowatt hour at the switchboard; in air plants, per 1,000 cubic feet of air per hour at a given pressure at the primary receiver. It is regretted that, along with the other data in the table, the total volume of air compressed in the period covered was not given; the pressure was 85 pounds; the piston displacement of the compressors, as indicated by the revolution counters, was not supplied. It is, of course, understood that the fuel consumption listed covers the entire plant with all auxiliaries. It may be further noted at this point that this fuel includes that required to furnish steam for a 175-horse-power compound engine running Mill No. 1, and connected to the boilers of the power house adjacent to the mill. The Gray Cañon plant is blessed with cheap coal. The table shows that the new boilers permitted the use of a cheaper grade of coal than the old.

The possibilities of water power as applied to quarry work are best developed along lines similar to those just described, by application in a central air-compressing plant. If the water power is close at hand, or within a distance of one to five miles, depending largely upon the nature of the intervening country, waterwheel-driven compressors, direct connected or driven by other approved methods, will secure the highest economy of compression. Transmission and distribution of the air power must follow the lines of accepted practice, largely as outlined in the Gray Cañon plant. If the water power is far distant from the quarry, whether several scattered powers are to be made use of at one point, or whether one large power is to be applied in several locations, electric generators and electric transmission will deliver the power. At the quarry, motor-driven compressors will convert electric power to compressed air, which will be properly distributed and applied in standard pneumatic quarry machines, with reheaters as the last refinement of economy.

In the electrically-driven air-compressing plant at the quarry, one or two large units will give place to a number of smaller compressing sets; for the quarry load is a varying load—often widely varying. If the electric motors are alternating-current machines (as they will be in the majority of cases), the compressor unit will be essentially constant in speed. Therefore varying load cannot be handled by varying speeds; hence other schemes, such as air unloaders and controllers, must be used to proportion the effective piston displacement to the load. These devices, however, do not economically provide for load variations exceeding, say, 20 per cent. of normal. Greater variation than this must be provided for by the subdivided unit system and by automatic relay unit control. But the problems of electrical air compression are distinct, and will not be discussed here. It is enough to say that the electrical compressor is a success—an established fact—and is sure to be a powerful factor in the future of the quarry.

The distribution of compressed air in quarries is so well understood that there need be no appreciable loss in transmission. The loop system, successfully applied at the Gray Cañon, is a solution of the problem of combining maximum flexibility and carrying capacity, with minimum cost and loss of power. Every tee should be protected by a valve in each branch. Gate valves are better than globe valves, and rising-stem types show at a glance whether the valve is closed or open. All lines should be securely anchored, correctly supported, and guarded against strains in expansion and contraction. For this last purpose, offsets are better and cheaper than slip joints. The importance of proper grading of the lines, and the value of moisture traps in removing entrained moisture, have already been emphasized. Every receiver aids in this drying process; in fact, it is almost impossible to have too much receiver capacity in a system. It has been seen how advantageously old boilers can be worked into a distribution scheme. It would seem impossible to avoid leakage in a pipe system; yet the Gray Cañon plant, with its miles of pipe and its countless valves, joints and fittings, retains full air pressure over night. Seeming impossibilities have been overcome by careful workmanship and watchful attention.

The heat generated in the compression of air represents an equivalent amount of work lost. Reheating the compressed air before it is used in the engine permits the



THE GRAY CANON QUARRY OF THE CLEVELAND STONE COMPANY, AT NORTH AMHERST, OHIO.

recovery of this work at small expense; it furthermore gives the advantages of expansive working in the cylinders. It has been conclusively shown that efficient reheating will give a net gain of power as high as 30 per cent. This is equivalent in effect to a 23 per cent. reduction in boiler and compressor capacity, for a given output, and a corresponding decrease in the fuel bill. Of course there is a point at which the cost of reheating fuel offsets the advantage gained by reheating; this point is conditioned by too many factors to be discussed here. It is shown, by the table, how insignificant is the cost of reheating; the reheaters used are simple structures of pipe and brick, made on the ground. The limit to which reheating may be carried is fixed by the lubricant used in the engine cylinders. Even with air at 600 degrees Fahrenheit, so short a cut-off and so great an expansion are permitted that the mean cylinder temperature is maintained well below the charring and flashing points of high-grade oils. The problem of reheating air has not received its due measure of attention. In the judicious application of heat to the air used lies an important feature of quarry economics.

I have stated that the old steam machines were retained under the new system; they were simply put in good condition and were found ready for work. On cut-off engines the cut-off was retained, in some cases actually shortened, thanks to the use of reheaters; on non-expansive engines heating has been applied simply to secure a greater air economy. Pressure is automatically maintained under varying load by a cut-off governor on the steam valves.

An examination of the table shows that with air as a power, the number of active machines was reduced from that of the old system, yet the output of the quarry has been increased since the new plant was installed. This apparent paradox is due principally to the increased constant pressure and the increased "activity" of the air. Under the old scheme, pipe condensation gave not only a reduced pressure, but also wet steam, and consequently sluggish machines. Under the present system full receiver pressure is available on the piston of every machine, while reheating only adds efficiency. Where formerly 40, 50, 60 pounds of steam pressure were used, depending upon the length of pipe line and the fireman's convenience, to-day standard air pressure of 85 pounds is everywhere instantly available at the turn of a valve. The word "instantly" is deserving of special notice; with the former system, the machine runners often had to wait for steam; pipe lines had to be drained or thawed in winter.

The labor force has been reduced, not only in the number of attendants at boilers and machines put out of commission, but also in the number of general laborers formerly retained for the repair and upkeep of the steam plant. Added to this saving is an intangible but a very real gain arising from the pleasanter quarry conditions. There is no steam and smoke settling in the "hole," darkening day into twilight, making more stifling and unbearable the heat of summer, and wetting the clothing and chilling body and spirit in winter. There is, as it were, a spiritual uplift to the small army of laborers. Better men are attracted; old men are glad to remain. The working season knows no weather limitation; the quarries are operated the year round. The quality of the rock product is improved, for there is now no smoke to discolor the rock faces, no coal and ash scattered about to stain the rock surface under rain and snow. There has thus been added to the organization of these three quarries a great flexibility, an overload capacity, which will be of incalculable value at times of sudden heavy demands, as when a huge contract is secured on early delivery. The success of the Gray Cañon power system has removed the compressed-air quarry plant from the limbo of experiment and placed it in the field of established fact.

Study of a Riedler Air Compressor.

The accompanying diagrams illustrate the Riedler Air Compressor and its discharge valves as described in the paper "Study of a Riedler Air Compressor," by Arthur P. Hall, which appeared in the last number of COMPRESSED AIR. Figure 1 shows the general type of the machine and Figure 2 the discharge valve. The reader is referred to the July issue for further information.

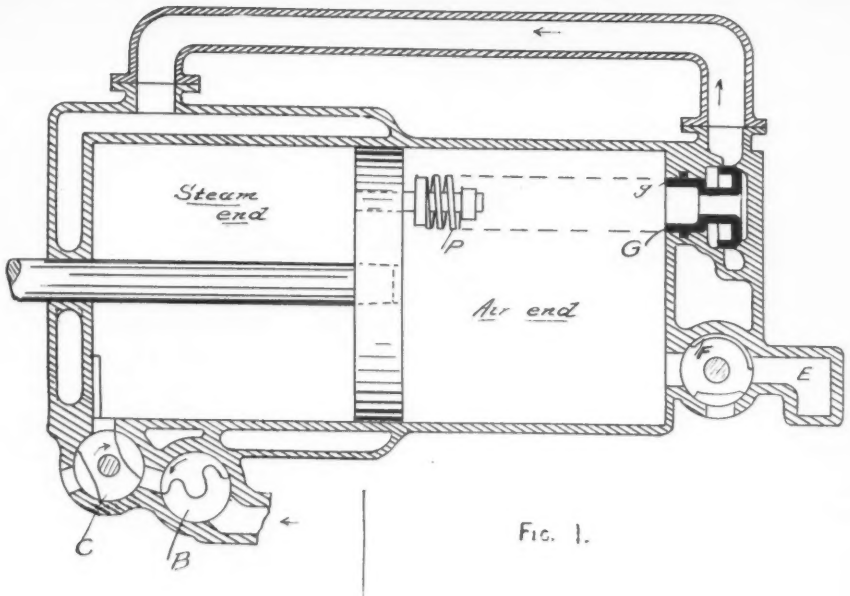
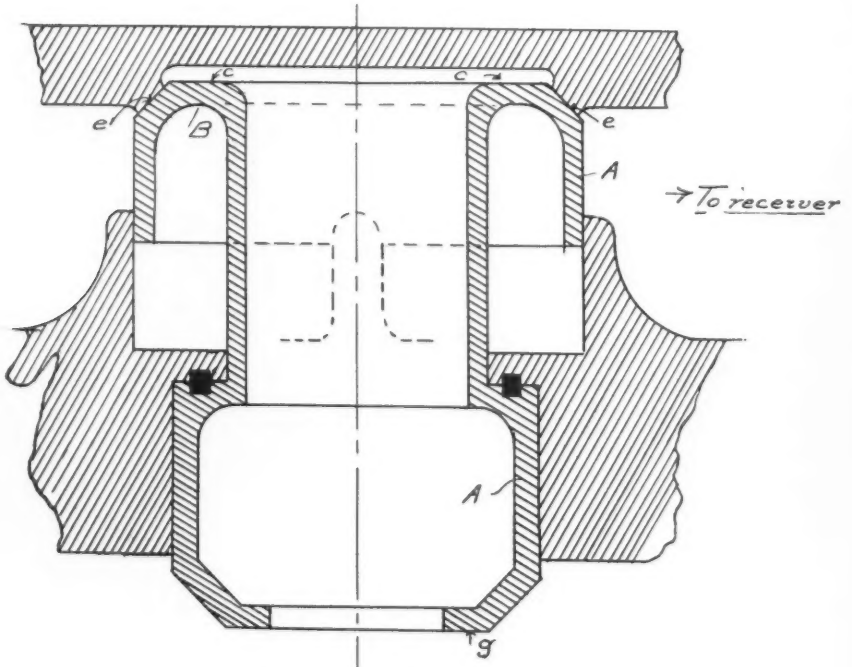


FIG. 1.



DISCHARGE VALVE

FIG. 2.

The Dangers and Difficulties of Tunnel Boring.

The joining of one of the twin passages of the 12¼-mile Simplon tunnel on February 24 last, brought to an end most of the difficulties the engineers of that great enterprise had to surmount, and made the completion of the work fairly easy. Never before in the history of land tunneling have such formidable obstacles been met and successfully overcome. Not only was there trouble from cracking and crumbling of the masonry walls by the great pressures they sustained, but also formidable springs of hot water were encountered, which made the temperature unbearable and flooded the workings. These hot springs made the boring of this celebrated tunnel through the Simplon range almost as difficult and dangerous a piece of work as is the boring of the North River and East River tunnels in New York City. Attention was called to this latter work, and the difficulties which attend it by an accident which happened in the northernmost tunnel under the East River on March 27. This tunnel is being driven from the Brooklyn side of the river. It starts just west of Clinton street, and has reached a point in the river 1,400 feet away, or about 20 feet beyond the stringpiece at the foot of Joralemon street and between Piers 17 and 18. It is being driven by a tunneling shield similar to that used in 1868 by the late editor of this journal, Mr. Alfred E. Beach, in constructing an experimental tunnel under Broadway. While this shield (with which our readers are doubtless familiar, as we have described it at various times) operates very well in solid earth, it having been used not only for land tunnels, but also for tunnels under water in various places, when it is used near the river bed in soft sand, such as is found in the East River, there are liable to be "blowouts," as they are termed, and these are exceedingly dangerous. As the shield is forced forward through the sand, the latter is kept from oozing in by means of compressed air. If it were possible to carry on the work with the air pressure at the point where it is equal to the pressure of mud and water at the top of the shield, there would be no difficulty; but as the bottom of the shield is nearly 20 feet below its top, a greater pressure than is needed at the top has to be employed in order to keep out the sand at the bottom. The result is that if the sand is not very firm or thick, the excessive air pressure at the top of the shield is liable to make an opening through the river bed and blow out, whereupon, if the air pressure is not maintained, water will flow in. It was just such an occurrence as this that cost the lives of twenty men in 1880, during the first attempt at driving a tunnel under the North River, although at this time work was being carried on without a shield, and great risks were taken. The men doing the work in the East River tunnel knew that the river bed was treacherous, and they were provided with sandbags with which to stop up any small leak that might start, before it should have a chance to enlarge. In the accident mentioned, a workman in the upper part of the shield discovered a leak, and called to his mates below to hand up a sandbag. They did this, and he was about to stop up the leak when a large hole was blown through the river bed, and the rapidly escaping air forced the workman up through it and the water above and projected him, in a column of water, a few feet above the surface. He was rescued by men on the pier, and, save for a wetting, was unhurt. The other men in the shield managed to make their escape and shut the doors behind them. One of these men became wedged while making his escape, and it took half an hour to dislodge him. The air pressure meanwhile was kept at the point to which it fell as a result of the blowout. This was only a few pounds lower than the pressure that had been maintained.

In order to resume work, it was necessary to stop up the hole in the river bed. This was done by sinking a large sheet of canvas and loading it with bags of sand. The water was then pumped out of the shield, and work was begun once more. The river bed above the shield is only 8 or 9 feet thick where the accident occurred, and there is about 19 feet of water.

The air pressure in excess of atmospheric used to hold up this weight of water and sand was only just sufficient to balance the pressure of the water and sand at the bottom of the shield, and it caused a few pounds per square inch more pressure than was needed at the top. A bowlder was encountered and blasted a short time before the leak was discovered, and it is probable that the blast so

loosened the sand that when the air once started to escape it easily broke through a large passage for itself, and kept escaping until the air and water pressures became equalized. This accident is an example of what may happen when boring a tunnel under a river and near the surface of the river bed. In constructing the North River tunnel it was necessary to thicken the river bed on the line of the tunnel, in order to prevent blowouts. In the present instance these have been avoided only by the greatest vigilance.

The system of constructing a tunnel from the surface by putting together the upper half, sinking it, placing it on piles, and then constructing the bottom half on a concrete foundation beneath—a system which was employed in the subway tunnel beneath the Harlem River successfully, and which we described in our July 2, 1904, issue—does away with the dangers we have mentioned, and is also more expeditious. We understand it is to be employed in constructing a tunnel across the North River at 42d street in the near future.—*Scientific American.*

Pressure-Retaining Device for Air Brakes.

A press dispatch describes an interesting air brake invention made by Mr. James W. Brown, of Minneapolis, Minn., in the shape of a pressure-retaining device which is under the direct control of the engineer. The ordinary pressure-retaining device now in use is operated by the brakemen from the top of the cars and is subject to the neglect and carelessness of a class of employees that has, too often, little interest in the efficient handling of trains. On mountain roads and other roads having long grades the handling of trains, with the ordinary air brake equipment, is a matter of much risk, and runaway trains are not an infrequent occurrence. It is realized that all the factors that contribute to the control of the train should be under the immediate control of the engineer and that the responsibility should not be divided. With the ordinary pressure-retaining device the exhaust pipe leading from the triple valve may be closed by a three-way cock, so that the exhaust must escape by a weight-loaded valve, which gives a back-pressure of about 15 pounds per square inch. In this way a constant pressure of 15 pounds per square inch may be retained in the brake cylinders while the train pipe and auxiliary reservoirs are being recharged. Without this device a train is without control during the recharging period, and it is during this critical time that so many trains get beyond control.

The Brown semi-automatic retainer is a valve placed close to the triple valve and connected to the train pipe and the triple exhaust pipe. The valve closing the triple valve exhaust is connected to a piston communicating with the train pipe, but the piston is restrained from closing the exhaust port by a spring, which exerts the equivalent of 85 pounds per square inch, so that the standard train pipe pressure of 70 pounds cannot open it, consequently the retainer is ordinarily out of service and the brakes can be released as quickly as if there were no retainers on the train. If the engineer wishes to use the retainers he places the brake valve in full release position and charges the train pipe to 90 pounds. This pressure opens a valve and allows the air to enter the retainer cylinder, forcing the piston back, closing the exhaust port and establishing direct communication between the retainer cylinder and the train pipe through a passage. The pressure in the train pipe must now be reduced below 30 pounds before the spring can move the piston to normal position and open the exhaust. Now, with the brakes applied, there is still 50 pounds in the train pipe, or 20 pounds more than is needed to hold the retainers in the service position, so that there is no danger of their releasing. As soon as the brakes are set the brake valve is placed in running position and the train pipe recharged. The triples will move to release position, but the retainer will hold the air in the brake cylinder. When it becomes necessary to reset the brakes, a reduction of 5 to 10 pounds will give full braking pressure, owing to the air already in the brake cylinder. After the last application, near the bottom of the hill, the brake valve is placed on lap, and when the bottom is reached, the train pipe pressure is reduced below 30 pounds, when the spring will force the piston forward, closing the passage to the train pipe and opening the exhaust. Now, when the train pipe is recharged, the triples move to release and the air from the brake cylinder is free to pass through the retainer to the at-

mosphere. The retainers are now out of service and will remain so until the pressure in the train pipe is raised high enough to open the valve controlling the passage of air from the train pipe to the retainer cylinder—that is, 85 pounds.—*Railway Machinery.*

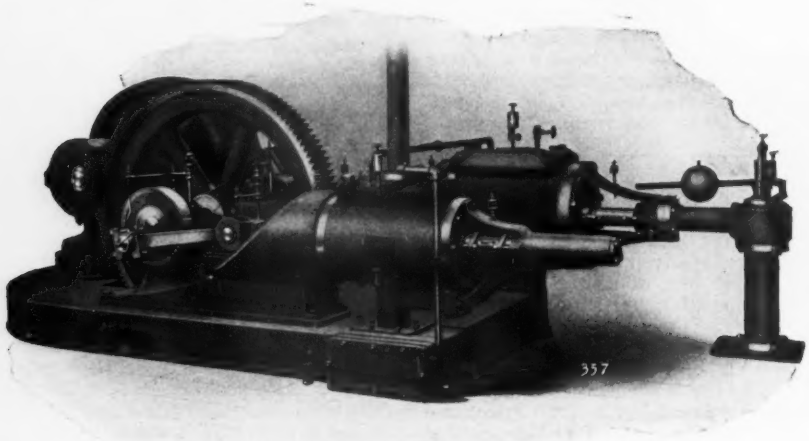
The Electrical Compressor Plant of the Chicago & Northwestern Railway Terminal, Chicago, Ill.

The air power plant at the Terminal Station of the Chicago and Northwestern Railway in Chicago is a fine example of the best modern practice in the application of electric power to the compression of air for the many purposes so characteristic of railway yard work.

The plant is located in a small brick building in the rear of the main Terminal Station, close to the river and adjacent to the extensive passenger yards of the company. This building comprises two rooms, in one of which are the steam boilers for the heating system of the station. In the other section is located the electrical and pneumatic apparatus.

Alternating current is taken from the city mains of the Chicago Edison Company and passed through transformers reducing it to the working voltage. Part of it is used directly on low-voltage alternating circuits. The remainder is passed through rotary converters or motor generators and delivered as direct current for power purposes.

The air compressor plant is made up of two Ingersoll-Sergeant standard power-driven compressors, of the type designated by the makers as Class "JC". They are duplex two-stage machines, with air cylinders, frames, and bearings, mounted on a solid cast-iron bed-plate which encloses the horizontal intercooler between the cylinders. Both high and low pressure cylinders are fitted with the standard Ingersoll-Sergeant piston inlet valve and regulation is secured by the marker's standard choking controller on the low pressure intake. This device, acting to throttle the air intake passage, is controlled by receiver pressure and automatically regulates the volume of air compressed and consequently the amount of power consumed—to the demand for air from the power system. The compressors run at constant speed, the controller simply varying the effective piston displacement with varying load. The machines have a stroke of 12 inches, with air cylinders 12¼ and 18¼ inches in diameter. At their speed of 130 revolutions per minute the free air capacity of

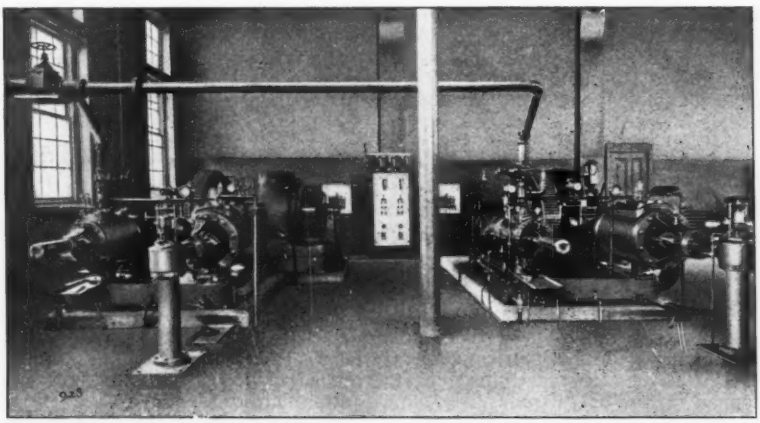


ELECTRICALLY-DRIVEN INGERSOLL-SERGEANT CLASS "JC" AIR COMPRESSOR.

each unit is 455 cubic feet per minute. The pressure used in this plant is 70 to 80 pounds gauge.

The sub-base is extended in each compressor to support the driving motors, which are General Electric direct-current machines, rated at 80 horse power and 510 revolutions per minute, on 220 volts. A pinion on the motor shaft gears directly with the teeth on the compressor flywheel, which is of standard weight for machines of this capacity. The gears are protected by proper guards. The units run with a remarkable freedom from vibration and noise.

house, made up of a large upper and lower horizontal header, connected by a number of small vertical pipes. This arrangement freely exposed to the air, precipitates whatever moisture may remain in the air after leaving the primary receiver; and this water is withdrawn from the lower header. From this cooler, air lines radiate throughout the yard, supplying power to the pneumatic switch and signal system controlling the movement of trains in the terminal track system. Secondary air receivers are also located at suitable places. The air is used almost entirely in this system of



INTERIOR OF POWER HOUSE AT THE TERMINAL STATION OF THE CHICAGO AND NORTHWESTERN RAILWAY.

Independent concrete foundations are used. Each unit has its own automatic oiling system on all bearings, fed from a central tank. The drip is recovered and filtered. Sight-feed oilers care for cylinder lubrications. The illustration shows the arrangement of the air plant. The machines are side by side, the switchboard, rheostats, meters, etc., mounted in front of and between them. An intake duct, supplying both compressors, leads under the floor to the open air and rises beside the power house, terminating in a screen cover for the exclusion of dust and cinders from the yards.

The discharge pipes from the two unite in an air main leading to the primary receiver outside the plant. Provision is made for draining this receiver. From this point, the line leads to a system of cooling tubes to the west of the power

switches and signals. But a small portion is diverted to the boiler room, where it is applied in a small air lift pumping outfit which supplies water to the terminal. The engineers in charge report an excellent performance of this equipment, which has been in severe and continuous service for several years.

Project for Tunneling under the East River, New York.

The method of tunneling that was employed in building the easterly half of the Harlem River tunnel of the New York Rapid Transit Subway forms the basis of a plan that has been submitted to the Rapid Transit Commission of New York City by Mr. D. D. McBean for the proposed roadway or combined street car and

roadway tunnels under the North and East Rivers. The construction of the easterly half of the Harlem River tunnel was described in *The Engineering Record*, May 14, 1904, and the successful manner in which Mr. McBean carried it out indicates that the same method can be applied in building larger tunnels and in deeper water than was encountered in that work. Practically all of the operations on that work which offered obstructions to navigation and many of the accurate details requiring intricate work have been overcome in the present plans.

The outline of the plan is to build a tunnel having two 30-foot roadways, with an arched roof of cross-braced built-up steel plate girders imbedded in concrete, with a continuous cover of sheet-steel plates riveted to the girders, waterproofed and protected by concrete. The girders in the roof arch are supported at the middle on a longitudinal row of columns and at the ends on bearing plates in the monolithic concrete sidewalls. The floor is also of monolithic concrete, laid on a pile foundation in soft material.

The site of the tunnel is to be dredged to a few feet below the level of the springing line of the arch, piles driven in rows over the site, sawed off near the bottom of the excavation and capped. The roof of the tunnel is to be built in convenient lengths of 100 feet or more, in floating open-topped boxes, or caissons, a temporary wooden floor laid on the bottom of the arch, and the ends of the section closed with sheet-steel diaphragms. As each section is completed the caisson will be scuttled and one end of it removed, so it may be pulled from beneath the floating section of the tunnel arch. The section will then be floated over its site, weighted and lowered into place by tackles on scows in a manner similar to that followed in lowering and placing the sections of the Harlem River tunnel.

When each section is in position heavy sheeting, placed getween guides attached temporarily to each section and lowered with it, will be driven longitudinally along both sides. The sheeting will be driven with followers and held in place by bolting a vertical steel plate, fixed longitudinally to the sheet-steel air-tight arch cover near the springing line on each side, through the sheetings to heavy outside longitudinal timber guide walings. The adjoining arch sections will be connected by bolting together outside flanges fixed to the continuous sheet-steel arch cover and the joint covered with concrete. The excavation outside the sheeting will then be back-filled to the top of the roof of the tunnel. When the sections have been connected the remaining material under the arch will be excavated to sub-grade by men working under air pressure in the chamber formed by the arch and the sheeting driven at the sides, the concrete sidewalls and floor being built as this excavation progresses.

The feasibility of constructing a tunnel in this manner was demonstrated under adverse conditions in building the Harlem River tunnel. The depth of water over the site of the proposed East River tunnels is as great as 70 feet in places, with the river bottom varying from soft mud to solid rock, and the chief difficulty in employing the methods contemplated in the proposed plans in this depth of water will doubtless be encountered in driving piles to temporarily support the sections of the tunnel arch. Mr. McBean states, however, that he has successfully driven square timber piles with special guides and followers in as great depths as will be encountered on any of the proposed work.

The depths at which tunnels have to be driven to procure head room sufficient to insure safety from blowouts in soft mud can be reduced by this method to the required harbor depth, as the extrados of the tunnel arch at the crown may be placed at any depth desired. The length of the tunnel approaches could be much reduced by thus raising the tunnel grades, and in the proposed plan the roadway portion of the tunnel is to be terminated at the bulkhead lines and the teams hoisted to the surface with elevators. The car tracks may then be extended in a smaller tunnel under the streets to connect with the subways and open roadway approaches entirely avoided.—*Engineering Record.*

Notes.

F. L. Sayer has succeeded Geo. H. Gibson as head of the Department of Publicity of the International Steam Pump Company.

The Engineer (English) for June 3 and 9 contained an article on the "Production of Very Low Temperatures by the Compression of Air and Hydrogen."

The Norwich Compressed Air Power Company has taken over the business at Norwich, Conn., of the Continental Air Power Company, and will conduct it in the future.

The Hinds Air Compressor Company, of Cripple Creek, Col., has been incorporated with a capital of $50,000. The incorporators are Myrtle Hinds, Miss M. J. Watson and Jas. Smith, all of Cripple Creek.

Owing to unforeseen difficulties which have appeared in the completion of the Simplon Tunnel, the formal opening of that tunnel will not be held in October, but is likely to be postponed until some time next year.

Members of the Pneumatic Tube Commission, appointed by the Post Office Department, have been visiting Chicago and inspecting the pneumatic tube service in that city. Their inspection is made with a view of extending the present service.

Readell & Co., Ltd., of Ipswich, Eng., has placed a new line of air compressors on the market. A special feature of the machines is that they are arranged for direct communication to electric motors without the intervention of any gearing, yet maintaining only two bearings in the complete machine.

The Boston Elevated Railway has now completed the equipment of all its cars with a compressed air device for opening and closing the side doors of the cars by the train man. This makes it possible to use the side doors on all trains and at all hours. It is expected that this will greatly improve the service.

To render a compressed air plant efficient, the pipes and receivers must be of liberal size and inspected frequently in search of leaks, which, when occurring, must be stopped. Flange joints for at least every other section of pipe are advisable in air and water pipe lines.—*Mining and Scientific Press.*

Air does not become liquid by reason of pressure, no matter how great, until the critical temperature is reached. The compression of air always generates heat, but heat passes away by radiation. It is stated that air may be compressed as a gas until it is more dense than it is in the liquid state.—*Mining and Scientific Press.*

The Ingersoll-Rand Company has taken possession of its new offices on the fourteenth floor of the Bowling Green Building, No. 11 Broadway, New York. The offices of the Ingersoll-Sergeant Drill Company, at No. 26 Cortlandt street, and the Rand Drill Company, at No. 128 Broadway, were given up August 1, and the united forces moved to the new offices.

A press dispatch from Paris is to the effect that consideration is now being given to the projects for the tunneling of Mont Faucille and Mont Blanc. The piercing of Mont Faucille will put Geneva in direct communication with Paris, and that of Mont Blanc will open to France direct traffic into Italy without passing through foreign territory. The object is to repair the losses in traffic suffered by France through the piercing of the Simplon tunnel.

Air compressers run by electric power are not uncommon about mines. The air is employed in drilling, running hoists, both above and below ground, and where the receivers are large and the pressure high—100 pounds per square inch—an installation of this character possesses some advantages when applied to hoisting. If the power is suddenly shut off, the air plant has usually sufficient expansive power in reserve to bring the skip to the surface.—*Mining and Scientific Press.*

The plan for a great underground pneumatic tube system in London, for the dispatch of letters and parcels, seems to have been definitely killed for the present by the adverse decision of the committee of the House of Commons. One of the advantages claimed for the plan was that it would relieve the congestion of the streets by dispensing with a large number of vehicles. But it seemed to be held that the scheme was still too much in the experimental stage. London had one experience, years ago, with a pneumatic tube delivery, which proved unsuccessful, but it is explained that the general plan was defective, parcels being accumulated faster than they could be handled, so that there was no saving in time.—*Ex.*

A new water works lake tunnel for Detroit, Mich., has just been completed. The tunnel is 3,160 feet long, centre to centre of shafts, has an internal diameter of 10 feet, and a four-ring brick lining. There was 26 feet of clay between the bottom of the river and the top of the excavation. The greatest depth of water over the tunnel is 30 feet. The tunnel bore, which was 13 feet in diameter, was through clay containing pockets of sand. Air pressure of 12 to 32 pounds was used, and no shield was employed. There was no loss of life during the construction of either the tunnel or shafts. The river intake crib will not be completed until some time next fall. Mr. Clarence W. Hubbell, M. Am. Soc. C. E., is civil engineer to the Water Board of Detroit.—*Engineering News.*

The operation of cleansing and renovating stone and brick surfaces by a sand-blast is being conducted on a commercial basis by Farnham (Limited), of Victoria street. The sand-blast is produced by an air-compressor, either fixed or portable, the air being conveyed to an atomizer which picks up the sand, which is carried through a hose and projected through a nozzle against the surface to be cleansed. The compressor is driven by an electric or petrol motor. A preservation process carried out by the injection of liquid paraffin wax to the stone or brick work, which has been previously dried and heated, is claimed to preserve the surfaces from the disintegrating effects of the atmosphere, gases, and moisture for an indefinite period.—*London Times (Eng.)*

An air compressor has been patented by Mr. Charles H. Scott, of the High Orchard Iron Works, Gloucester, Eng., which has several novel features. The vertically reciprocating piston is cored out with passages of large area, and has fitted at the top a light suction valve having a diameter almost as large as the piston. The end of the valve stem is hardened, and the top end of the connecting rod above the piston pin comes in contact with the end of the valve stem during the suction stroke, owing to the angularity of the rod, so lifting the suction valve. The valve is returned to its seat by a spring. The delivery valve is of slightly larger diameter than, and has its seating on, the top end of the cylinder. The two valves are dished and come practically into contact (concave to convex) with one another at the top of the stroke so as to have the minimum of clearance.

The Pedrick & Ayer Company, of Plainfield, N. J., has put on the market a small portable pneumatic punch, designed especially for railroad work, to fill the need of such a tool in roundhouses and railroad shops for doing light punching of all kinds. The tool weighs about 190 pounds and may be swung from an overhead trolley, in which position one man can punch the holes along a tank plate much more rapidly than five or six men can handle a heavy sheet through a stationary punch. It may also be set on a bench; the hand lever can be removed and a foot lever attached, which makes it a very compact stationary punch for the copper shop and roundhouse and for making repairs to tanks, stacks, ash pans and front ends. It has a maximum capacity of 9-16 holes in ¼ inch steel plate with 90 pounds air pressure, and is fitted with suitable dies. It will drive ¼ inch rivets cold.

"In some localities," said the representative of a whistle manufacturer, "they now use no surface cars, in place of the gong, air whistles blown by compressed air pumped into a tank carried on the car. The whistles used on the cars of the subway and elevated roads in this city are air whistles, blown by compressed air in this manner.

"The air whistle is similar in design and appearance to the steam whistle, but different in some details of its construction and in the adjustment of its parts, to adapt it to the use of air instead of steam.

"On many power boats not driven by steam there are now used air whistles. These whistles are blown by compressed air from a tank kept filled by a pump operated with power from that supplied for driving the boat, or by the boat's machinery. But we supply also nowadays independent air whistles, pump and gage, the pump of which can be operated by hand; and such outfits are not costly.

"We are now selling air whistles for automobiles."—*New York Sun.*

The cleaning and ventilation of a workshop is to be effected by a novel system installed at the Singer Manufacturing Co.'s new works in Scotland, by the J. M.

Adam Company, pneumatic engineers, of Glasgow. There are eight cabinet-making workshops, 200 feet, by 80 feet, containing specialized machine tools, and immediately from each tool the sawdust and chips are drawn as produced, and conveyed by air current to the main boilers, into the furnaces of which they are fed continuously and automatically. The fans are motor-driven, and consist of nine equal units in three groups of three each, concentrated in three main pressure ducts carried on a bridge of five spans, each 50 feet long, and about 30 feet high, supported on steel lattice columns across the yard between the factory and the boiler house. The bridge will also carry an elevated rope traction tramway, with a service of small trucks conveying to the same destination broken wood and other refuse too heavy for air current transmission. The power absorbed will be approximately 150 b. horse power.—*Work* (Eng.).

The classification of excavation causes so much trouble at times and is made in so many ways, that it is of interest to notice the system adopted for the main canal of the North Platte project of the U. S. Reclamation Service, involving 2,800,000 cubic yards of earthwork and 150,000 cubic yards of rock work. Four classes have been adopted, as follows: Class 1: All material that can be plowed by an average four-horse or mule team, each animal weighing not less than 1,400 pounds, attached to a suitable breaking plow, all well handled by at least three men. Also all loose material occurring in the above that can be loaded into a scraper by two men. Class 2: Indurated material of all kinds which cannot be plowed as in Class 1, but which requires loosening by powder and can then be removed in scrapers, and including the formation known as Brule clay. Class 3: All loose material in which large rocks occur to such an extent as to prevent the use of plow or scraper, but excluding masses exceeding 1 cubic yard in volume. Class 4: All rock in masses greater than 1 cubic yard and requiring drilling and blasting.—*Engineering Record.*

With increase in altitude the barometric or atmospheric pressure falls from 14.7 pounds per square inch at sea-level to about 10 pounds at 10,000 feet above sea-level. Since the density of the air decreases with its pressure it is obvious that at such an altitude the total weight of air handled by a given displacement is considerably less than at sea-level; and that to fill any volume—a rock-drill cylinder, for instance—with air compressed to 90 pounds, a greater free-air displacement will be necessary than would be required at sea-level. The relative capacities of a given displacement to do work—as in rock drills or pumps—at varying altitudes are indicated in the following table:

Feet above Sea Level	Barometer Inches	Relative Capacities	Feet above Sea Level	Barometer Inches	Relative Capacities
0	30	1.000	4500	25.26	.867
500	29.42	.983	5000	24.78	.856
1000	28.87	.967	6000	23.85	.827
1500	28.33	.954	7000	22.95	.800
2000	27.79	.938	8000	22.10	.772
2500	27.27	.924	9000	21.22	.750
3000	26.76	.909	10000	20.43	.725
3500	26.25	.894	12000	18.92	.677
4000	25.75	.879			

—*Popular Mechanics.*

During the past three years I have done considerable outside spraying. Nearly all this spraying has been done in peach orchards in a radius of one mile from my plant, and the lime and sulphur mixture has been used, excepting some later spraying with the Bordeaux. I have two compressed air-rigs, and have covered about 150 acres of peach orchards during the early spring. At the plant the mixtures are made, and also the tanks are charged with compressed air while being filled with the mixture. I have one man in the orchard who does all the spraying, and a boy to deliver the charged rigs to him and return the empty rig to the plant for recharging. It requires about thirty minutes to blow out a tank full of mixture, 120 gallons. I furnish and make the mixture, and apply it to bearing trees at the rate of 3 cents per gallon. This is really cheaper than the average grower with the usual hand outfit can apply it, counting the cost of their labor. Most of the larger plants here are equipped with air compressors, and employ this power instead of gasoline mixture and other power pumps. Several are co-operative plants, furnish mixture and power for the members and some outsiders. The introduction of this advanced method of spraying has shorn the

San Jose of its terrors, as well as fungus diseases.—W. H. Owen, in *Rural New Yorker.*

In connection with the ventilation of the New York Subway John W. Young, who has studied the problem from the standpoint of a railway builder and engineer, is quoted by the New York *American* as saying:

"You must remember that with suction you will not get the heavy air out at all. The fans will draw only the heated air that is stirred up by the trains. There will always be a layer of dead, cool air at the bottom of the tube along the tracks, heavily charged with unwholesome gas and impurities. The trains rushing through this merely push it aside as a ship does water.

"But by releasing cold, condensed air along the bottom of the Subway at points between the stations you make fresh air expel impure air so fast that impurities have not time to collect in dangerous quantities.

"Any contractor will tell you how the blast of air is used in digging tunnels or in mines to ventilate the workings. For $50,000 the City could build a compressed air plant that would furnish complete ventilation for the Subway. The most pressure needed in the longest stretch of closed subway, where the openings to the street are farthest apart, would not be more than required to operate three or four ordinary rock drills."

A disadvantage of the conventional pool or billiard table is its large dimensions, which prohibit its use in a house of ordinary size, unless located in the cellar, which generally does not offer attactive surroundings. Realizing this limitation, an Indianapolis man has conceived the idea of constructing pneumatic cues, which are very much smaller than the regulation cue sticks. By the use of this invention the game of pool or billiards may be played upon a smaller table than is generally used, and a correspondingly smaller room may be employed. The invention also permits the arrangement of smaller tables in closer proximity, without the players at once interfering with the players at adjacent tables. An important feature of the pneumatic cue stick is that it permits the players to play a more perfect game, and the cue reduces the difficulty of the game, without reducing its scientific basis, and at the same time adds interest and novelty.

In construction the cue is simple. It includes a short, hollow stick, provided at one end with a movable tip and at the other with a piston and rubber bulb, which furnishes the propelling power. Pressure upon the bulb will force the cue stick out with any desired degree of force, and the quickness with which the pressure is applied to the air bulb determines the shooting strength, as the harder the ball is hit. —*Philadelphia Record.*

The rise in temperature in compressing air in the usual types of compressors found in the mining regions can be greatly reduced in most cases if the air be conducted to the compressing cylinders from the outside open air, instead of within the building, as is most commonly the case. The freezing up of an air pipe line during cold weather is due to the moisture in the air, which congeals, clogging the pipe. To obviate this difficulty a sort of condenser called an "aftercooler" is made through which the air passes, the moisture being condensed and settling to the bottom of the aftercooler from which it may be drawn off. If desired, the air, now comparatively free from moisture, may be reheated for use. A large-sized air receiver, situated 20 or 30 feet from the compressor, has a tendency to take a large percentage of moisture out of the atmosphere. Where the pipe line from the compressor to the point of use is long—over 1,000 feet—it is good practice to put in a second receiver. It not only extracts more water from the compressed air, but gives a larger volume of air upon which to rely in case of a sudden unexpected stoppage of the compressor. At some mines having air-compressing plants, with water or electrical power, and steam (usually the original plant) as auxiliary, the air line is connected with the boilers when not otherwise in use to give greater capacity to the air plant.—*Mining and Scientific Press.*

Anyone possessing, or able to obtain an old bicycle pump can, without much difficulty, make a small air compressor which will pump a bicycle tire or run a toy steam engine. The next thing necessary is a pulley about 8 or 9 inches in diameter and 2 inches thick.

Mount this pulley on a piece of ¼ or ½ inch steel rod for a shaft. Bend about 2 inches of one end of the shaft at a right

angle and force the rod through a hole in the centre of the pulley, hammer it into the wood and fasten it with a staple.

Remove the handle from the bicycle pump, heat the end of the piston rod to a bright glow and hammer it flat. Drill a hole in the flat part large enough for a nail to pass through easily. To the foot-piece on the bottom of the pump solder a hinge and then screw the loose part of the hinge to the baseboard.

In putting the compressor together mount the shaft of the pulley on pieces of sheet brass having holes drilled to make an easy fit. These pieces of sheet brass should be screwed fast in a hole in one end of a 2x4 inch timber 2 feet long. Nail the end of the piston rod, through the hole drilled, to the pulley and belt whatever means of generating power you may have to the air compressor which is now complete. A small electric motor will work the apparatus nicely for pumping bicycle tires or other work of that nature.—By E. H. Klipstein, East Orange, New Jersey, in *Popular Mechanics.*

At the recent meeting of the Air-Brake Association Mr. Robert Burgess, in a paper on the maintenance of air-brake hose, quoted some interesting figures taken from the storekeeper's records on a large railroad owning about 25,000 cars. The cost of maintaining the hose on these cars for one year was, in round numbers, $30,000. This figure is probably much higher than the average, and an analysis of the itemized records is therefore of particular interest as showing where the careless or extravagant practices can be traced. During the year 27,600 hose were bought and fitted up complete. But during the same period only 19,750 coupling gaskets were bought. Manifestly, therefore, not only were a large number of new hose sent out with old gaskets, but the number of gaskets issued to repairmen must have been very limited. The result was that the trainmen and repairmen were encouraged to wedge up the couplings to keep them tight with the old gaskets, and, in consequence of this bad practice, a large number of hose and angle-cocks were torn off and damaged. By attempting to save gaskets that cost 4 cents, hose costing 75 cents were destroyed.

More than 6,500 new couplings were bought, showing that of the total number of hose fitted up, about 25 per cent. of the couplings were either lost or so badly damaged as to render them useless. Over 12,000 hose nipples were ordered, which would indicate that when a hose was torn off only the larger end was returned for refitting. Hose clamps to the number of 37,000 were also bought, showing that the repairmen, in remounting hose, almost invariably threw away the old clamps. Another interesting feature of the investigation which was made in this case was the ignorance shown regarding the storage of hose. Most of the storekeepers were under the impression that the hose should be kept in a dry atmosphere, and in most places it was stored in the upper part of the storehouse. A large number of porous and cracked hose was the natural result.—*Railroad Gazette.*

Nowadays no dentist's office is modernly equipped without a compressed air outfit, and the number of uses for the air-blast found in dentistry is astonishing. Not only does it make the dentist's work easier, but it also renders it less painful to the patient. In a paper read before the Michigan State Dental Association at Lansing recently, Dr. George Zederbaum enumerates the uses he has found for compressed air in his own office.

There are two outfits practical for the same purpose. One consists of a small pump connected by a pulley to an electric motor. When the motor is set in motion the pump compresses the air into a storage tank, which, by means of an air gauge, accurately registers the pressure of air stored. From the storage tank leads the outlet pipe, guarded by a suitable valve. This, of course, requires an electric current. The other outfit is in reach of all those in small towns, as it depends on a water supply, no very high pressure being necessary. The air pump is attached to the city water supply pipe, which keeps the desired pressure of air in the storage tank automatically. Either apparatus described may be had for $25 or $30.

The compressed air is used for drying cavities, which are to be filled, a current of air applied for two minutes being sufficient for cooling compounds used in taking impressions and bites, such as wax and gutta percha, and which, because of their plasticity, must be applied warm; in treating injuries which are hard to reach and see, using either liquid applied by means of a pointed atomizer tube and

the air, or powder applied by means of a glass pipe. In preparing cavities it is frequently necessary to blow out the chips and uncomfortable heat is generated by the revolving bur. The point of operation may be kept free from chips and the bur be prevented from heating by wiring a small rubber tube around the engine cable down to the hand-piece and turning on the air pressure. The opening in the tube need not be larger than 1/32 of an inch.

For deodorizing malodorous mouths, spraying a solution of lavender or other perfume about the room to rid it of disagreeable odors, drying up the mouth in bridge or crown work, or for connecting to the blow-pipe in soldering, the air current will be found equally efficient. By turning it squarely into the face of a patient who has taken an anæsthetic, or one who has fainted after an extraction, the patient may be quickly revived—a pleasanter means than putting water on the face.—*Popular Mechanics.*

A revised edition of Progressive Questions and Answers on the Air Brake, both Westinghouse and New York systems, for beginners and advanced students, has just been issued by the Air-Brake Association.

Westinghouse System.—The book contains a thorough description of all the Westinghouse apparatus, construction and operation, disorders, their location and correction. This department contains more than 800 questions and answers, and nearly 100 first-class illustrations, besides many general questions and answers.

New York System.—All parts of the New York apparatus are thoroughly explained, including disorders, their location and remedies. Nearly 600 questions and answers are given in this department, supplemented by 80 splendid illustrations, and it is one of the best, if not the best treatise on the New York air brake ever published.

In the introduction the publishers say: "The value of the original book of Questions and Answers on the Air Brake as compiled by the Air-Brake Association in 1896, is perhaps best estimated by the unusually large sale of sixty thousand copies up to the present time. This value is further forcibly expressed by the insistent demands of air-brake men for a revision of the original book, although there are many other air-brake books in this field which, to some persons, may appear overcrowded. Regardless of this fact, there seems to be a special field and demand for the Air-Brake Association's Book of Questions and Answers. It is to meet these demands, and also those of new conditions in modern railroad air-brake practice, that this revision has been made. Both the Westinghouse and New York systems have been exhaustively treated by specialists in these two companies, thus putting between the covers of one book authoritative and up-to-date information on the two brakes. That portion of the work pertaining to inspection, operation, repairs and maintenance has been performed by actual service men, expressly called in for the purpose from the firing line of daily experience. In this way there has been brought together the strongest revising corps obtainable to produce an air-brake book equally valuable to the beginner and to the advanced student—the former, if he applies himself, being fitted to pass any air-brake examination imposed, and the latter to be entertained and kept up-to-date in air construction and practice. As an addition to the library of the air-brake student, this book will be found indispensable."

This book is furnished in both leather and paper covers, and copies may be purchased from Mr. F. M. Nellis, Secretary, Air-Brake Association, 136 Liberty street, New York, N. Y.

Americans use more water than any other nation in the world. From earliest childhood they are taught not only to use water freely, but actually to waste it. Plenty of water has so long been a necessity that no one could be induced to accept any other belief. In the large cities millions of dollars have been spent in securing, improving and extending the municipal system of water works. Every day 398,925,628 gallons of water are pumped out of Lake Michigan into the homes of Chicago. Indeed there are few towns of 1,500 inhabitants without their water works.

A good water supply in a house is quite as essential to comfort and health as that of heat, and vastly more so than the question of artificial light. As people have gone out from the cities into the country they have installed various private systems of water supply, using gasoline or hot air engines, rams, and windmills to do

the pumping. The latest method is the pneumatic, which in first cost, is so low, and in operation so simple as to make a description of it interesting. And this system may be briefly explained as a strong steel tank filled partly with water and partly with compressed air. A pump to get the water into the tank and the usual service pipes to conduct the water where it is wanted complete the story.

To go into more detail it should first be stated that the success of the system depends more on the tank itself than all else. A tank which will hold water alone, at say 200 pounds pressure, may leak air at 70 pounds for the same reason that a basket which will hold a bushel of potatoes will leak sand, or a watch case which is waterproof will become filled with dust in time. Air is thinner than water and will pass through a smaller opening. By the pneumatic system a pressure of 40 pounds—which is more than is found in most city systems—will elevate water through pipes to a height of 93 feet or throw a stream into the air to 55 feet; 70 pounds pressure elevates in pipes to 160 feet, and throws a stream to 75 feet.

The tank can be placed in a basement, or shed and need not be directly over the cistern or well from which the supply is taken, no elevated reservoir is required; the tank should be of a size proportionate to the quantity used. Attached to the tank, preferably, but located elsewhere if necessary, is a special pump for forcing the water into the tank. For residences and similar requirements two to four pumpings a month are sufficient for all household purposes. The compression of the air in the tank is secured by pumping the water into the tank, not by allowing the tank to partly fill with water by gravity and then pumping in air. The pumping may be done by hand for the smaller systems, or by windmill, gas engine, electric motor or hydraulic rams, and the tanks have been built from 200 gallons capacity for a house up to 5,000 gallons for ranches. For systems using a large amount of water, as for instance a large apartment building in Louisville, Ky., which uses as high as 6,000 gallons an hour, the pumping obviously must be done by power. Where windmills or electric motors are used a self-acting regulator starts and stops the pump without any attention. For a medium size residence 5 to 10 minutes per day pumping by hand will suffice and is not especially hard work.—*Popular Mechanics.*

Apparently there is going to be no end to the Proctor chain of theatres. That enterprising manager has frequently announced his intention to add no more theatres to his circuit, but his natural born energy will not let him rest content, and every few months one wakes up to read of another Proctor playhouse. The latest link in the chain is Troy. In that city Mr. Proctor has secured, for a long term of years, the famous Griswold Opera House, which has been used for high-class stars and combinations. Early in September it will reopen as "Proctor's Griswold," and if these all pleasant plans do not go astray Troy will enjoy during the coming season the greatest all star vaudeville entertainment they have ever dreamed of. Trojans are to be congratulated.

The August *Century* will bring the second of Mr. Frank J. Sprague's papers on "The Electric Railway," giving special attention to later experiments and the present state of the art. It is Mr. Sprague's opinion that every road presents a special problem, and that the wisdom of adopting electricity can be determined only by a most careful analysis of all the conditions affecting it.

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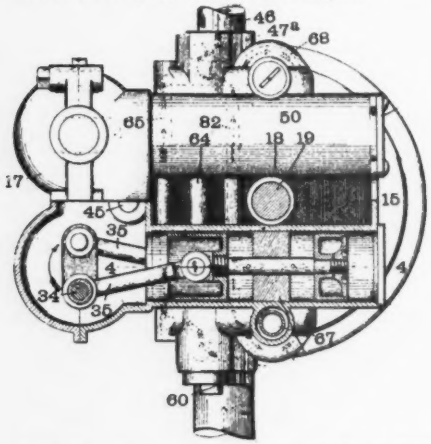
U. S. PATENTS GRANTED JUNE, 1905.

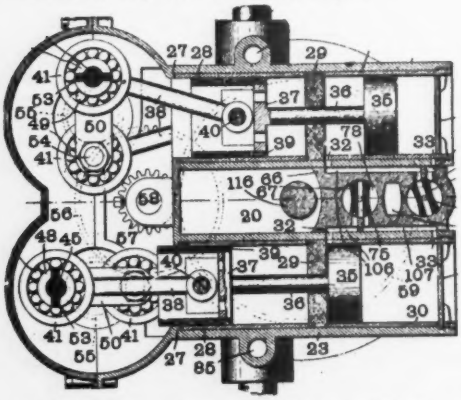
Specially prepared for COMPRESSED AIR.

791,846. PNEUMATIC DRILL. James Whitelaw, St. Louis, Mo. Filed Jan. 21, 1903. Renewed Nov. 3, 1904. Serial No. 231,202.



A fluid motor, two sets of cylinders, the cylinders of each set being arranged in tandem and consisting of a single-acting cylinder and double-acting cylinder, pistons in said cylinders, and means for admitting motive fluid to both cylinders of one set and to the double-acting cylinder of the other set and exhausting the motive fluid from the double-acting cylinder of said first-named set and from both cylinders of said second-named set.

791,847. PNEUMATIC DRILL. James Whitelaw, St. Louis, Mo. Filed Sept. 26, 1903. Renewed Nov. 3, 1904. Serial No. 231,203.



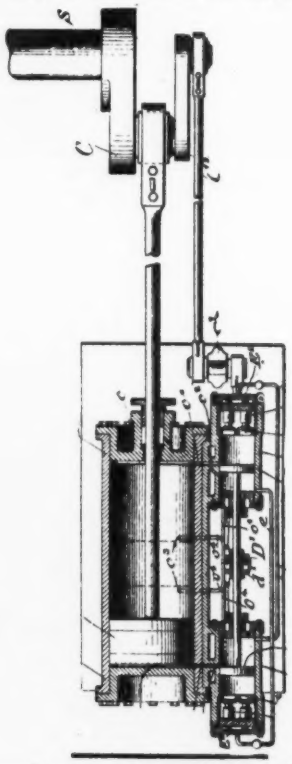
A fluid motor, a housing containing cylinders and provided with flat contact-surfaces, pistons in said cylinders, mechanism for transmitting the power from said pistons, a gear-casing carried by said housing, and a removable valve-casing carried by said housing and extending between said cylinders to supply fluid thereto, said valve-casing being provided with flat contact-surfaces co-operating with the contact-surfaces of said housing.

791,605. SLACK ADJUSTING DEVICE FOR AIR-BRAKES. Lynton T. Block, St. Louis, Mo. Filed December 5, 1903. Serial No. 183,987.

791,787. PNEUMATIC BREAST-STRAP. Clarence T. Howard, Rosedale, Kans., assignor of one-half to James O. McVey, Kansas City, Mo. Filed Apr. 28, 1902. Serial No. 105,042.

791,788. PNEUMATIC HORSE-COLLAR. Clarence T. Howard, Rosedale, Kans., assignor of one-half to James O. McVey, Kansas City, Mo. Filed Apr. 28, 1902. Serial No. 105,042.

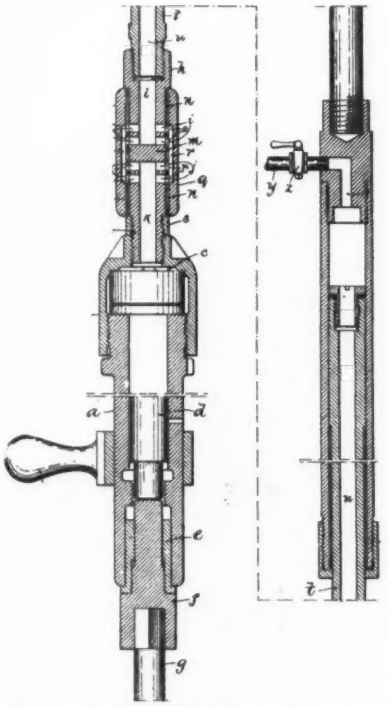
791,896. VALVE-MOTION FOR AIR-COMPRESSORS. Fritz Gerb, New York, N. Y. Filed Sept. 16, 1902. Serial No. 123,559.



The combination, with an air-compressing main cylinder and piston, suction valves located at the ends of the main cylinder, and means for actuating the suction-valves of piston-valves, each comprising a cylinder and a piston movable therein, at the ends of the main cylinder, means

for operating the piston-valves, a rod connecting the piston-valve pistons, channels connecting the ends of the main cylinder with the cylinders of the piston-valves, outlet-valves at the outer ends of the piston-valve cylinders, and pipes connecting the inner end of one piston-valve cylinder with the outer end of the other piston-valve cylinder.

792,023. DRILL. Charles H. Haeseler, Philadelphia, Pa., assignor to The Ingersoll-Sergeant Drill Company, New York, N. Y., a Corporation of West Virginia. Filed Jan. 6, 1905. Serial No. 239,957.

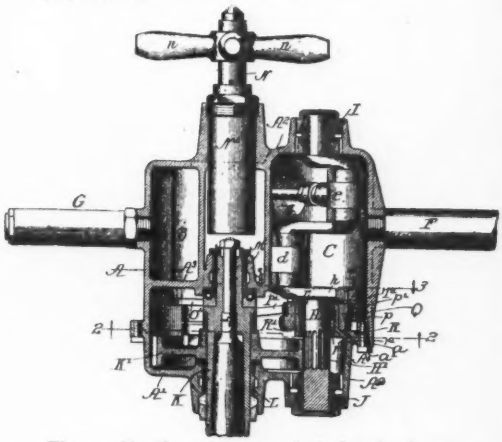


A combined hammer-drill and feeder, the combination, with the feed cylinder and piston, of the hammer-drill secured to the feed-piston, said feed-cylinder having a continuous passage extending from the source of motive-fluid supply to the interior of the hammer-drill and including the pressure area back of the feed-piston, a throttle-valve between said pressure area and the hammer-drill for controlling the hammer-drill and a throttle-valve back of said pressure area for controlling the feed-piston, substantially as described.

A combined hammer-drill and feeder, the combination with the drill-cylinder and working tool connected thereto so as to rotate therewith, of the feed-piston connected with the drill-cylinder so as to turn therewith, the feed-cylinder having a pressure-chamber back of the feed-piston, means to admit motive fluid to said pressure-chamber, a passage extending from said pressure-chamber through said piston to the drill-cylinder, a throttle-valve interposed in said passage and adapted to be grasped by one hand of the operator, and a handle secured to the drill-cylinder and adapted to be grasped by the other hand of operator to turn the working tool during its operation, substantially as described.

792,152. ENGINEER'S VALVE FOR AIR-BRAKES. James F. McElroy, Albany, N. Y., assignor to Consolidated Car Heating Company, a Corporation of West Virginia. Filed Nov. 1, 1904. Serial No. 230,932.

792,281. PORTABLE PNEUMATIC DRILL. Reinhold A. Norling, Aurora, Ill., assignor to Aurora Automatic Machinery Company, Aurora, Ill., a Corporation of Illinois. Filed July 20, 1904. Serial No. 217,371.



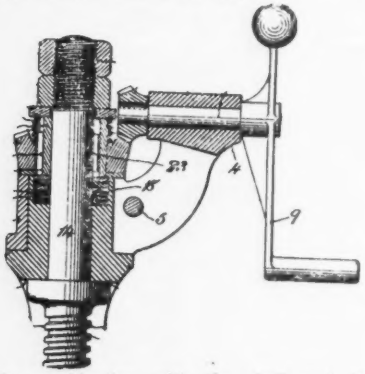
The combination with a crank-shaft, of a bearing-plate provided with rigidly-attached bearing-sleeve, driving connections between the said eccentric and the crank-shaft consisting of a stud on the eccentric and a radial slot formed in one of the crank-arms of the crank-shaft and adapted to receive said stud on the eccentric, a counterbalance-weight for the crank-shaft, and a disk to which said weight is attached, said disk being located on the crank-shaft adjacent to the eccentric and provided with a slot through which passes the said stud on the eccentric.

792,290. PNEUMATIC TIRE. Corydon S. Sears, Toledo, Ohio. Filed Sept. 22, 1904. Serial No. 225,406.

792,306. MOTOR-OPERATED DUMPING-CAR. Carl P. Astrom, East Orange, N. J., assignor to M. H. Treadwell & Co., a Corporation of New York. Filed Sept. 6, 1904. Serial No. 223,379.

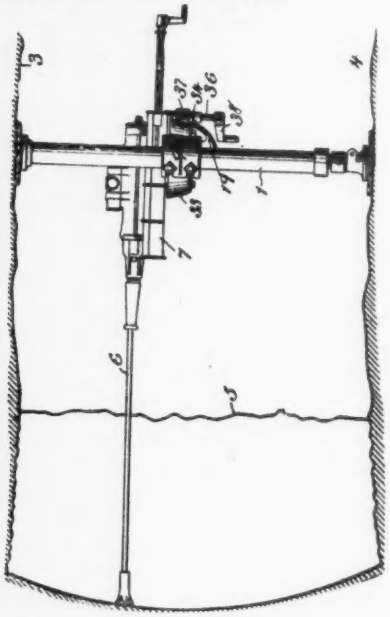
A motor-operated dumping-car and the like, a reciprocating motor-cylinder, a fixed piston and piston-rod for said cylinder, connections between said cylinder and the dumping-car body, a member on said cylinder provided with an opening, a member on a fixed part of the car also provided with an opening, and a locking-pin adapted to be received through said openings when the cylinder has been shifted so that said openings are opposite, substantially as and for the purposes set forth.

792,287. CHANNELING-MACHINE. William Prellwitz, Easton, Pa., assignor to The Ingersoll-Sergeant Drill Company, New York, N. Y., a Corporation of West Virginia. Filed Sept. 2, 1904. Serial No. 223,101.



The combination with the shell and feed-screw, of gear connected with the feed-screw, driving gear carried by the shell and means for adjusting the driving gear in different radial positions with relation to the axis of the feed-screw.

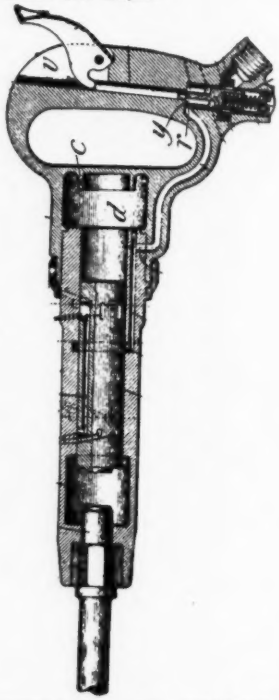
792,288. CHANNELING-MACHINE. William Prellwitz, Easton, Pa., assignor to The Ingersoll Sergeant Drill Company, New York, N. Y., a corporation of West Virginia. Filed Sept. 2, 1904. Serial No. 223,103.



The combination with a supporting-column, of a trunnion removably secured to the column with its axis parallel with the axis of the column and a shell-support mounted in a plane transverse to the axis of the trunnion.

The combination with a suitable support and a two-part trunnion arranged to embrace the support, one of the said trunnion parts being provided with a worm-wheel segment, of a shell-support arranged to embrace the said trunnion, the shell-support being provided with a worm adapted to engage the worm-wheel segment to rotate the shell-support on the trunnion about the axis of the support and trunnion.

792,333. PNEUMATIC TOOL. Herman Leineweber, South Chicago, Ill., assignor to International Tool Company of Chicago, Chicago, Ill., a Corporation of Illinois. Filed Nov. 5, 1904. Serial No. 231,491.



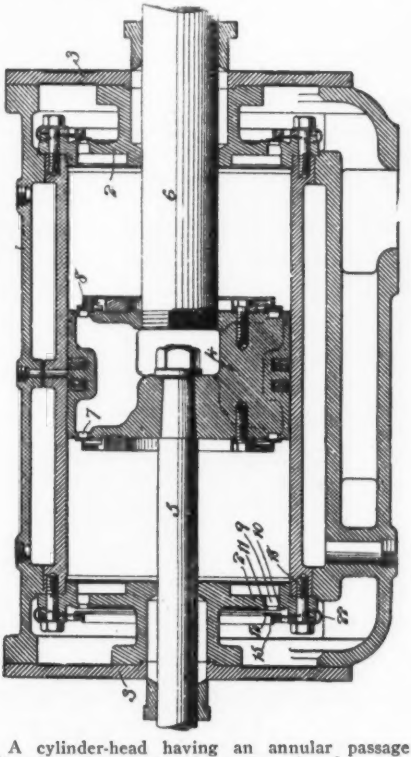
A pneumatic tool, the combination with a casing carrying at one end of the tool and containing a reciprocable piston, of a handle provided with a passage through which to introduce air-pressure into the casing for actuating the piston, and pressure-regulating mechanism on the handle comprising a tube crossing said passage and provided with elongated ports registering therewith, a spring-pressed valve confined in said tube and having ducts leading through it with their inlet ends extending to different planes to be depressed successively into registration with said ports, and a lever fulcrumed on the handle for operating said valve, substantially as and for the purpose set forth.

792,390. PNEUMATIC SPOKE-RIVETER, Chris Borg, Chicago, Ill., assignor to International Harvester Company, a Corporation of New Jersey. Filed Dec. 21, 1904. Serial No. 237,738.

A pneumatic spoke-riveter, in combination, a frame, spoke-gripping jaws and a heading-tool pivotally mounted thereon, a toggle connection between the said heading-tool and frame, a toggle connection between the said spoke-gripping jaws, links connecting the toggle-links on the spoke-gripping jaws with the toggle-links between the heading-tool and frame and also with said heading-tool, and single means for actuating both the spoke-gripping jaws and heading-tool, substantially as described.

792,673. GRIP-TREAD FOR PNEUMATIC TIRES. William J. Smith, Canastota, N. Y., assignor of one-half to Leslie G. Fischer, Canostota, N. Y. Filed Feb. 24, 1905. Serial No. 247,152.

792,788. COMPRESSOR. William Prellwitz, Easton, Pa., assignor to the The Ingersoll-Sergeant Drill Company, New York, N. Y., a Corporation of West Virginia. Filed Apr. 25, 1904. Serial No. 204,744.

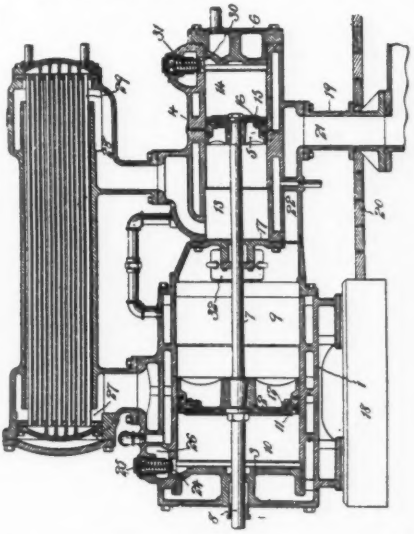


A cylinder-head having an annular passage therethrough, an annular valve therefor comprising a ring portion and a flange, and an annular plate secured to the head and spaced therefrom, the inner wall of the plate engaging the outer wall of the flange, forming a guide for the valve and limiting its outward movement.

792,757. FLUID-PRESSURE REGULATOR. Jacob Cloos, Milwaukee, Wis., assignor to Cloos Engineering Company, a Corporation of Wisconsin. Filed Aug. 12, 1904. Serial No. 220,502.

A pressure-reducing mechanism comprising parts arranged so as to form a self-adjusting expansion passageway connecting the sources of primary and secondary pressure and a throttle mechanism acting at the opening of said passageway and acted on by variation in the secondary pressure.

792,790. COMPRESSOR. William Prellwitz, Easton, Pa., assignor to The Ingersoll-Sergeant Drill Company, New York, N. Y., a Corporation of West Virginia. Filed June 2, 1904. Serial No. 210,827.

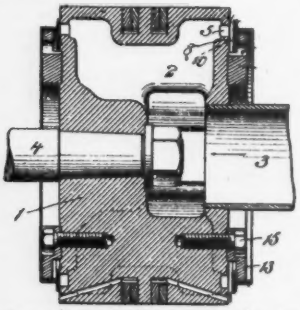


A compressor, separated low and high pressure cylinders, valved pistons therefor, inlets at the approximate ends of the cylinders and outlets at their other ends, and means for leading the compressed fluid from the outlet of the low-pressure cylinder to the inlet of the high-pressure cylinder.

793,166. AIR-TANK AND MEANS FOR SUPPLYING SAME. Edward Walther, Davenport, Iowa. Filed Sept. 1, 1904. Serial No. 222,957.

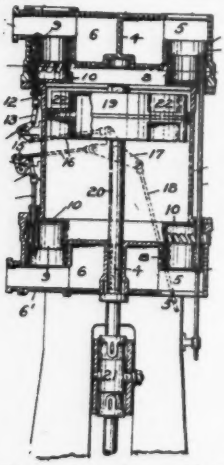
In combination with a tank provided with a sliding reservoir-bell, air-supply pipe in communication with said tank and bell, a series of compressing-tanks and bells one in communication wtih each air-supply pipe, means for causing the compressing-bells to be raised and filled with air, and mechanism controllable by the fall of the reservoir-bell for causing the fall of the compressing-bells in succession or simultaneously for supplying air to the main bell.

792,789. COMPRESSOR. William Prellwitz, Easton, Pa., assignor to The Ingersoll-Sergeant Drill Company, New York, N. Y., a Corporation of West Virginia. Filed Apr. 25, 1904. Serial No. 204,745.



A hollow piston having an annular passage in its face, an annular valve therefor and a plate secured to the piston engaging the valve, forming a guide for the valve and limiting its outward movement, and holes through the plate for permitting the passage of the fluid by the inside wall of the valve.

793,380. BLOWING-ENGINE. Albert T. Keller, Wilkinsburg, Pa. Filed Dec. 22, 1903. Serial No. 186,199.



In a blowing-engine, the combination with a cylinder, and a recessed piston, of valve-cages closed at their inner ends and open at their sides, the valve-cages extending endwise into the cylinder adjacent the periphery of the latter, the cages being constructed and arranged to communicate with the cylinder through all of their side openings, and balanced valves operative within the cages.

793,405. PNEUMATIC TIRE. Edward C. Teuscher, St. Louis, Mo. Filed Mar. 15, 1905. Serial No. 250,267.

793,490. HOSE CONNECTION FOR CARS. Henry A. Wise, Mammoth, W. Va. Filed Jan. 21, 1905. Serial No. 242,094.

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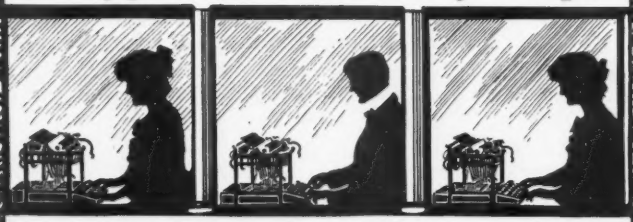

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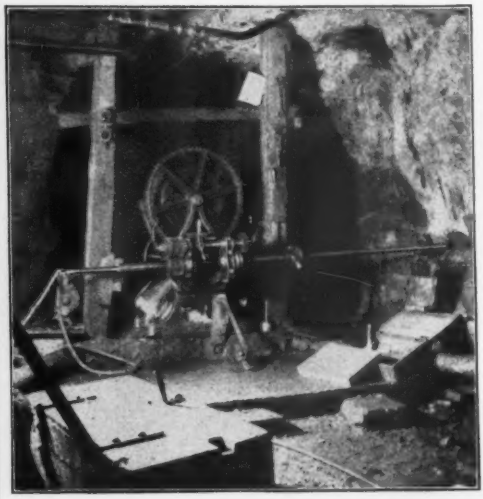

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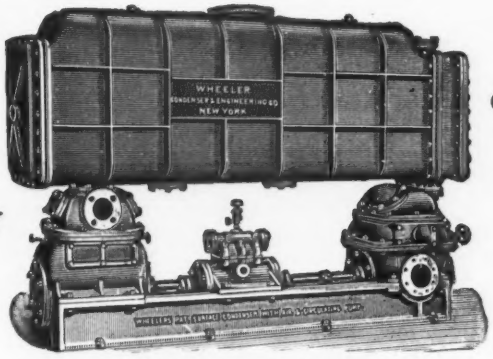

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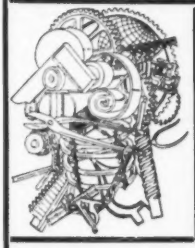

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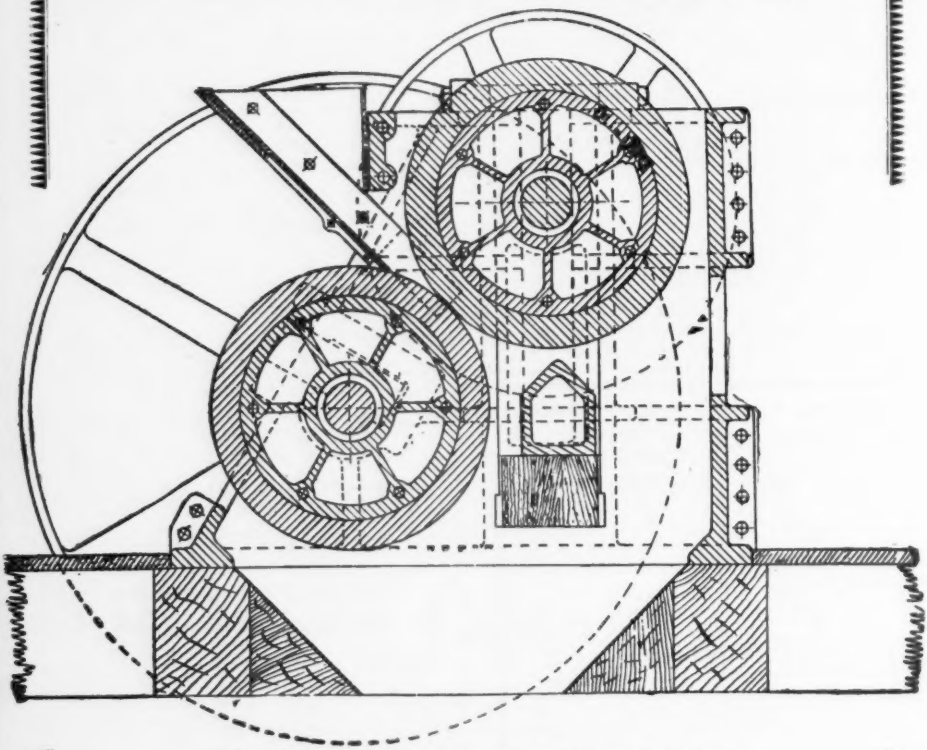

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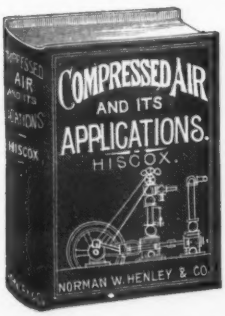

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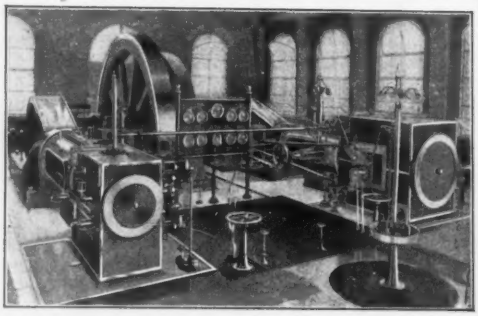

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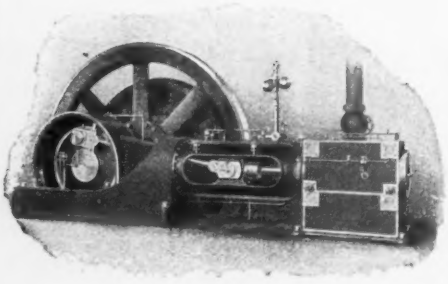

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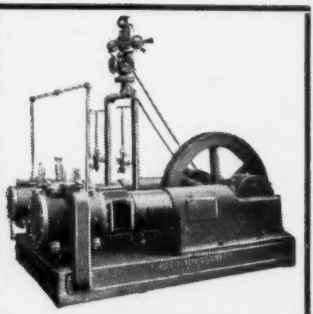
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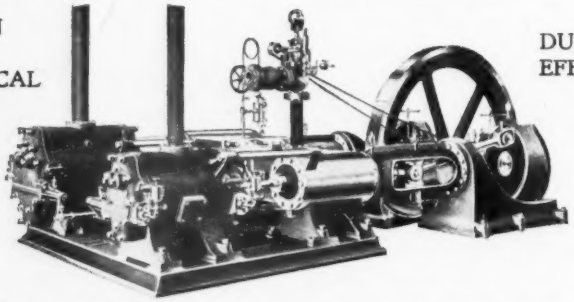

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